astroid Planning App User Guide

for app version 3.2.0

Table of Contents

Planning Overview

App Version: 3.2.0
Note: This user guide is intended only for the latest version of the Astroid Planning App listed above. Please refer to the planning version history for the complete listing of user guides.

™The .decimal Astroid Planning App is a cloud based software used for treatment planning of proton radiation therapy treatments. The Astroid Planning App is an interactive end user application that leverages the existing .decimal Dosimetry App functions for device creation, dose calculation, and optimization to facilitate efficient development of proton radiation treatment plans. The Planning App allows user interaction to capture treatment inputs and display results, and the Dosimetry App performs the calculations.

Access, permissions, and calculations for the Astroid Planning App are managed by the thinknode™ cloud platform service. By using this advanced cloud based technology, the Astroid Planning App is able to be perform well on any lightweight Windows computer, reducing the hardware and up-front setup costs that are typically associated with owning a radiation treatment planning system.

User Guide

The Planning App User Guide provides help material as well as walkthrough guides and a glossary of terms associated with the application.

Getting Started Basic setup and overview of the Astroid Planning App.

Tutorials Examples and guides for performing common tasks in the Astroid Planning App.

Known Limitations Known application limitations, defects, or inconsistencies.

ResultsAPI Accessing and using the Planning Results API.

Instructions For Use

The Astroid Planning App Instructions For Use outlines the intended use and user requirements of using the Planning App.

Overview Intended use and indications for use of

User Profile Recommended user education and

the application.

Warning Warning of potential misuse.

Product Features High level features of the astroid Planning App.

experience level.

Testing Responsibilities Testing responsibilities for ensuring correct setup and configuration of the astroid Planning App for clinical safety.

About

Note: This product received FDA 510(k) clearance as of May 15, 2018

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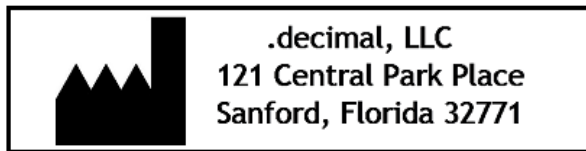
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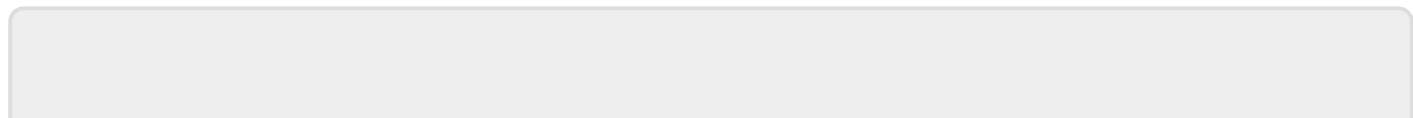
Last update: **2021/02/16 16:44**

Planning App Instructions for Use

Overview and Indications for Use

The Astroid Planning App is an interactive end user application for proton treatment planning for the intended use and primary purpose of enabling radiotherapy professionals to efficiently design and analyze proton radiotherapy treatment plans. This Astroid Planning App leverages the existing .decimal Astroid Dosimetry App [FDA 510(k) K150547], which is a library of treatment planning functions accessed through the Thinknode® cloud services framework, for device creation, dose calculation, optimization, and all other dosimetry and processing calculations. Since the Astroid Dosimetry App is responsible for performing the calculations, the scope of this Astroid Planning App is to be the interface for end users to input treatment planning data and review the results. Typical indications for use of this application are for the treatment of persons with cancer, over a wide range of potential disease locations. In the most common use case of the software, users will import patient data from existing imaging and contouring software programs, manage physician prescription and intent information, develop a proton treatment plan, and analyze the plan to determine how well it meets the physician's goals. Since the critical treatment planning functions and calculations are handled outside this software application, by a software of known quality and pedigree, the primary and most frequently used functions of this software are the record keeping service (for patient data storage), user interface controls, and visualization tools.

Furthermore, since the accuracy of information computed and displayed by an application such as this is very important to the proper treatment of patients, it is critical that users have the appropriate educational and clinical experience backgrounds to adequately understand and use the product. Additionally, since each radiotherapy treatment machine produces a unique beam of radiation, there is much responsibility on the end users to adequately commission and test this software over the full range of expected treatment conditions before the system is utilized for patient treatment.

User Responsibilities

It is the user's responsibility to commission and test the dose accuracy prior to patient treatment. This general liability on the end users should be understood and communicated to all users and a representative with signatory authority from each facility using Astroid must sign a *User Agreement* stating their understanding and acceptance of this responsibility.

Additionally, a site administrator with signatory authority will be required to sign an *End User License Agreement* on behalf of the facility indicating understanding of the responsibilities for quality, accuracy, and security described herein.

Clinical Safety

It is the responsibility that the user performs end-to-end testing prior to the clinical implementation of

Astroid. The user should follow accepted industry guideline (such as AAPM TG244) for the end-to-end testing. This testing should be performed by qualified personnel.

It is the responsibility of the facility to ensure that all users of the Astroid treatment planning system have had training on the Astroid product and possess the appropriate clinical education, experience, and (where applicable) licensure to develop clinical treatment plans. This includes, but is not limited to, the application training provided by Astroid staff.

It is recommended that users follow acceptable global standards during the commissioning of the Astroid product. During the clinical set up, the following should be tested to ensure clinical safety prior to treatment:

1. Geometric relationships of the hardware machine models
2. The dose algorithm
3. Data access and storage
4. Accuracy of the planning dose systems.

Warning

It is critical that all users read these Instructions for Use and the User Guide material carefully and completely and consult the provided User Guides and other training materials to ensure proper use of the application and proper interpretation of results.

> Prior to the delivery of any plan on a patient, users are responsible for performing patient specific QA to ensure clinical acceptability of the delivered dose distribution. Since users are responsible for testing the acceptability of the delivered dose before treatment, Astroid, its staff, and representatives shall not be liable for any mis-treatments that may result from use of the system.

Caution: Federal law restricts this device to sale by or on the order of a physician.

Intended Use

The Astroid Planning App is an interactive end user application that leverages the existing .decimal Astroid Dosimetry App library [FDA 510(k) K150547] of functions (accessed through the Thinknode® cloud services framework) for device creation, dose calculation, optimization, and many other purposes, for the intended use and primary purpose of enabling radiotherapy professionals to efficiently design and analyze proton radiotherapy treatment plans.

User Profile

The Astroid Planning App is a tool to develop radiotherapy treatment plans for delivery using a proton therapy system. Such plans are generally developed to meet the directives of a physician through a formal documented prescription. As such, the users of this application are expected to be supervised by an attending physician and should themselves be experienced in the physics and dosimetric characteristics of proton radiotherapy. Additionally, users are expected to have formal training in general radiotherapy techniques and best practices, proton therapy specific planning techniques, and general principles of patient safety and care. Most users will have college-level training or degrees, as well as licensure for their particular roles and responsibilities through their state, nation, or professional association. Users should also be well versed in regulations regarding protection of patient health information and have a basic understanding of standard practices regarding computer usage and security.

Product Features

In the most common, primary use case of the software, users will import patient data from existing imaging and contouring software programs, manage physician prescription and intent information, develop a proton treatment plan, and analyze the plan to determine how well it meets the physician's goals. Since the critical treatment planning functions and calculations are handled outside this software application, by a software of known quality and pedigree, the primary and most frequently used functions of this software are the record keeping service (for patient data storage via Thinknode®), user interface controls, and visualization tools. The Astroid Planning App software communicates with other treatment planning systems generally by sending & receiving files in various DICOM RT formats, although the extensive Application Programming Interface (API) of Thinknode® allows users to easily build their own export and import conversion applications. Since the accuracy of information computed and displayed by an application such as this is very important to the proper treatment of patients, it is critical that users have the appropriate educational and clinical experience backgrounds to adequately understand and use the product. Additionally, since each radiotherapy treatment machine produces a unique beam of radiation, there is much responsibility on the end users to adequately commission and test this software over the full range of expected treatment conditions before the system is utilized for patient treatment. It is this area that provides opportunity for the most likely incorrect use of the software, which would be poor or inadequate commissioning of the application (note many other cases of potential misuse have be designed out of the system by limiting allowed user interactions, providing warnings, and preventing unsafe or incompatible operations). This main misuse is mitigated by requiring that users understand that it is their responsibility to perform appropriate quality assurance measurements for every patient plan prior to treatment, which should independently confirm that the treatment plan information displayed within the Astroid Planning App adequately matches the actual, to be delivered, plan. Please note that such testing is a safety and regulatory requirement in most territories.

System Availability and Data Integrity

As with any cloud based application there is always concern with system availability and uptime. Astroid

makes use of caching at various system levels to improve performance and mitigate some of these concerns, however, this can never provide 100% assurance and reliability. Since customer has unique needs, specific business agreements will be entered into with each customer as appropriate to detail the reliability guarantees and assurances. Data integrity is generally a less variable concern, as Astroid's cloud storage providers strong guarantee the highest commercially available data redundancy and integrity limits (approaching 99.999999% per year). Data is transferred to and from the cloud services using secure transfer protocols, that guarantee error-free of transfer using common industry standard techniques (for more details please see the Thinknode IPC article). While Astroid has been designed with security in mind, users should understand that it is still their responsibility to ensure the system is accessed and controlled properly. Following international standards for IT risk management, such as IEC 80001-1, is therefore highly recommended.

Since data integrity is such a critical feature for application such as this, the Astroid Planning App automatically saves both the state of the application and the working record data on a timer (triggering every minute or less) as well as on exit of any create or edit event in the application. Additionally, each "save" event creates a new entry in the record's history log in Thinknode, which provides a log file for editing of all records and a ensures that patient records are saved securely on an independent medium so they are not lost in the event of a local system failure or crash.

Coordinates and Units of Measure

The following is a list of several important items that users should understand in regards to the information displays in the Astroid Planning Application:

- The Astroid Planning exclusively uses DICOM coordinate systems for display information (machine based coordinates are NOT available)
- All linear dimensions are shown in millimeters (mm)
- All angular dimensions are shown in degrees (deg)
- All radiation dose quantities will be shown with their corresponding units within the application (e.g. Gy(RBE) or %)
- All date/time values are provided in a *dd/mm/yyyy h:m:s* format using local time on a 24 hour clock
- All date and time notifications in Astroid should match current Windows OS date and time, including proper use of daylight savings time where appropriate (note: Astroid will display in 24 hour format, while Windows may display in am/pm depending on local settings)

Data Validation and Limits

Users are responsible for inputting a lot of data into the Astroid Planning App to develop clinical treatment plans. In the course of entering such data, there are opportunities for users to enter incorrect information. Although users are responsible for checking for such errors before clinical treatment, Astroid does provide some assistance in ensuring data limitations are met by a plan. Machine energy (range) limits, gantry angles, patient support (couch) angles, snout extensions, as well as shifter and aperture sizes and availability are all explicitly limited to user configured levels within the Astroid Planning App controls. Additionally, certain incompatible settings, such as zero thickness rinds and overlapping structure min/max constraints are also explicitly prevented within the Astroid user interface. Despite

these many data validation checks, some entries, such as min/max spot MU's are not validated within the Astroid user interface and users should include appropriate checks and warnings in their custom treatment plan reports to ensure such concerns are brought to the attention of all responsible parties before patient treatment begins. Such warnings should include a statement such as this (or similar): "CAUTION: SOME DATA ELEMENTS USED WERE OUTSIDE NORMAL RANGE".

Data Displays and Interpretation

Astroid contains many displays throughout the plan creation process. Please refer to the Astroid Tutorials.

Unauthorized Use

The Astroid Planning Application will contain sensitive patient information that is protected under various governmental regulations, therefore users must ensure they adequately follow all appropriate and applicable rules regarding how, where, and when their staff may access the application and its data. In order to facilitate proper usage and protections, Astroid has a robust user permissioning scheme, as well as industry standard options for configuring password requirements, as explained at the Thinknode Account Management Settings page. Since all application and data access requires user login credentials, it is important that site administrators implement a strong password policy and that all users understand the importance of maintaining secrecy of their password (i.e. passwords should never be shared among more than one user). It is these user credentials that protect the system and its data from unauthorized access and replication.

Access Control

Astroid (Thinknode) administrators have the ability to manage user access, passwords, and "lock" data records to prevent unwanted and unintended modification. Several features have specific access rights that can be configured, including the ability to lock data records, unlock data records, and delete data. By configuring these options, administrators can lock critical data records, such as beam models, equipment information, and other machine/site level data, such that only expressly authorized users can edit these fields. All critical site records such as these should be kept "locked" at all times, and should be unlocked by only be authorized users when expliciting desiring to edit said records (and locking them again after modification is complete). In addition to the practice of locking site data records, users are expected to establish a review process whereby a minimum of two authorized individuals will review all proposed site data changes (including beam models and equipment data) prior to updating the records in Thinknode (please note that at this time, all such records are downloaded, reviewed, and updated through the Thinknode Desktop Client, which is available for download here).

As Astroid is a cloud based application the site administrator will be responsible for the installation of Astroid on to the appropriate workstations. Each user should have an individual log in and password to access the planning app that prevents unauthorized access. Best practices should be followed.

For further information on access management and permission settings please refer to Thinknode IAM

Services. The Thinknode services provide two important considerations regarding your clinical data, first, the permission schemes and access control, provide effective control against unintentional and malicious data manipulation and the inherent storage redundancy of the cloud resources provides exception protection against data loss.

Known Limitations

For a list of known system issues and limitations please refer to the following articles for the Planning App and Dosimetry App, respectively.

Planning App Known Limitations

Dosimetry App Known Limitations

Release Management (Launcher)

The astroid Planning App is installed and launched from the astroid Launcher. The Launcher program provides the following functionality in regards to the Planning App:

1. Ensures that all users at a site are using the same version of the application
2. Ensures that the local Planning App client stays in sync with the latest release version (as set via Thinknode)
3. Provides user authentication and password management

When an application update is available via the astroid Launcher, the users will be required to install the App in the Launcher. This is accomplished by selecting the *Install* button for the specific app. Within a few minutes, the app should be downloaded and installed locally for the current user account. The user will then be able to launch the released app version from the astroid Launcher.

By using the astroid Launcher, users can log in to multiple realms with each realm using a different app version. This allows for scenarios of using non-clinical or research application versions from the same user account or workstation without the overhead of managing multiple installations. By logging into a realm, the user is required to use the installed client version for that realm.

Details regarding the specific requirements for computers on which the Launcher and Planning App client applications will be installed can be found on the System Requirements page.

Releasing a new App Version

In order to "push" a new Planning App version to the astroid Launcher, the dev-launcher realm must be updated to include an RKS entry for the new version of the application being released. The *client_version* record references the immutable data for the application package that contains the file system contents for the app versions (executable, dlls, etc.). The RKS hierarchy for this realm should be as follows:

- **<client>** (e.g.: planning)

- ○ **<client_version>** (e.g: 1.0.0-beta1)
    - References Immutable:

```
{
  "reference": "<immutable_id>",
  "path": "planning_app.exe"
}
```

- ○ **<client_version>**
- **<client>**
    - ○ **<client_version>**

For the launcher to register that an application should be installed for a realm, the *client* app with the *client_version* matching the dev-launcher RKS records should be installed into that realm. Please note that since the Launcher uses the *dev-launcher* realm for storing its records, all users of the Launcher will need permissions to read from this realm. Also, permissions to install/change app versions in Thinknode can be limited using Thinknode policies. Specifically, the *iam:realms:installVersions* permission is used to control this accessibility.

For Example: from the above RKS hierarchy example, the application client named *planning* with client version *1.0.0-beta1* should be installed in the intended clinical realm where users would need to access this version. When a user logs into the astroid Launcher and selects the clinical realm, they will have the ability to automatically install and launch that application version.

Release Notes

For the release notes for each version of the Planning Application, please refer to the .decimal Freshdesk Forum.

DICOM Receiver

Your site may have been provided with a DICOM receiver accessory package along with the astroid Planning App. This package may also require updating when installing new versions of the Planning App. The Planning App release notes will describe the necessity for such changes between versions and will also provide download links for obtaining the latest DICOM package software files. The DICOM receiver application includes a configuration file (receiver_config.json) that controls several important parameters for the DICOM receiver:

- local_ae_title: <public name for this dicom receiver>
- local_port: <local network communication port for this ae title>
- timeout: <max time allowed between files to consider them as a batch>
- storage_root_path: <local directory where DICOM files will be saved before upload begins>
- thinknode:
    - ○ user_token: <user access token from the DICOM upload account for your site>
    - ○ api_url: <full thinknode url for your site account>
    - ○ apps: <list of apps to get contexts for, must include: dosimetry, planning, and dicom>

- realm_name: <realm to which the DICOM data should be uploaded>
- account_name: <thinknode account name for your site>

Release Version Compatibility

The astroid Planning App is tested for version compatibility by .decimal prior to release to customers. However, it is still important for each site to independently test and verify the data integrity of each version prior to release at the site. Specifically, .decimal will test the version compatibility by:

- Adding manual and automatic data upgrades, as appropriate, for changes in the data model. When applicable, these changes are required to be sensible to the clinical environment and will be documented in the release notes.
- Performing a Thinknode GET /apm/apps/:account/:app/branches/:branch/statistics route comparing the current clinical version against the new version. This route will expose any missing data upgrades between the two app versions.
- Test the final dose calculations of matching patients between the two app versions to ensure the final doses exactly match (unless the dosimetry app has been otherwise indicated as changed).

Prior to releasing a new app version into a realm, it is imperative to ensure that the data is compatible between the existing version installed in the realm and the new version that is intended to be installed.

The following procedure shall be followed in order to safely release new versions of an application:

1. For the realm being upgraded copy the bucket data to a new test bucket so the new version can be tested prior to being released.
2. Install the release candidate app version into a test realm that is using the copied bucket.
3. Review the release notes for the new version and ensure you understand the changes.
   1. Check the release notes to determine if accessory applications may be impacted by the changes (e.g. DICOM receivers, report scripts) and complete any necessary steps to update or configure these items to work with the new test realm.
4. Login to the launcher and select the new test realm. Ensure the new app version is able to be installed and launched.
5. Open existing patients in the test realm. You should ensure each of the following for the existing patients and plans in the test realm:
   1. The patients and plans all open without errors.
   2. The final optimized dose result is the same as the previous version. Note: because a new version is released, the optimizer may rerun. But the result should be the same (Thinknode Immutable IDs may be used to confirm the exact matching of results).
   3. Perform any testing deemed appropriate in regards to the changes outlined in the release notes and required by regulatory guidelines for treatment planning system upgrades.
6. Once the release candidate has been thoroughly tested and is ready for release, notify all users at your site of the pending release and set an appropriate date and time for the release (it is generally good practice to stop all active clinical use during the upgrade so choose a time outside of normal clinical operating hours). At the designated date/time back up the bucket data in the clinical realm (data may have changed since the previous copy was made, so do not skip this step). **Keeping the latest backup of data is important as it provides the ability to roll back to a working clinical state should the release process fail.**

7. Using the Thinknode Client:
    1. Navigate to the Admin → Realms page.
    2. Uninstall the existing astroid app versions and install the new app versions.
    3. Login to the launcher and select the clinical realm. Ensure the new app version is able to be installed and launched.
    4. Open a patient plan and ensure it loads without error.
    5. Perform any other transfer testing necessary to ensure safe clinical release.

Realm Data Duplication or Backup

Data from within in a realm can be duplicated or backed up by manually copying the realm's bucket. This will produce a new bucket that is an exact replica of the original bucket and its data. This process allows for data backup, release testing, or data manipulation without adversely impacting the original bucket and data. To restore to a copied bucket, simply change the bucket to which the desired realm is currently associated via the Thinknode-Client.

If your user has the required thinknode permissions to read and manage buckets then you can backup data by running the copy buckets route (POST /iam/buckets/:bucket).

Astroid Patient Data Model

The following page describes the hierarchy of data used to manage patient data records within the Astroid planning environment.

Hierarchy

- **Patient**
    - **Course**
        - Prescriptions & Clinical Goals
        - Directive Structure List
        - **Patient Model**
            - Imaging Data
            - Structure Data
                - Active Variant
                - Variant List
        - **Plans**
            - RSP Data
            - Structures & Points
            - Calculation Grid
            - Treatment Room
            - Beams
                - Snout
                - Devices & Spot Options
                - DRRs

- Fraction Groups
    - Target
    - Constraint
    - Targets (1 or more)
        - Constraint (1 or more)
        - Beamset (1 or more)
            - Beams (1 or more)
- Constraints
- Objectives
- Optional Fluence Override
- Dose Results

Descriptions

- **Patient**:
    - A person receiving medical treatment. A Patient record contains basic personal information and demographics, as well as any number of treatment Courses.
    - This is where the patient name (prefix, given name, middle name, family name, suffix), medical record number (MRN#), sex (male, female, other, any) and date of birth (month, day, year) are stored.
- **Course**:
    - A prescribed regimen to be followed to treat a specific disease occurrence for a specific period of time. A Course will contain the physician's Intent and Directive information
    - The user will label the Course of treatment and specify the physician of record. The user has the option of adding a description of the course of treatment.
    - The intent captures the physician's purpose for this Course of radiation treatment. An Intent contains information about any protocols this patient is under, as well information regarding the disease site, body system, and body part (for both templating and billing purposes). An Intent can contain any number of Directives (although it's uncommon to have more than one). The user will define the type of treatment (curative, palliative, or prophylactic), as well as the treatment site at this level. A narrative of what the physician desires to achieve as a result of the course is also saved here.
    - The directive is the physician's orders for treating this Course. A Directive contains information about the prescription and other clinical goals for the Course.
    - A Course also contains any number of Patient Models.
- **Patient Model**:
    - A description of the patient's anatomy. Contains a single CT image set and all contour variants (targets and organs at risk) associated with these images. A Patient Models can contain any number of associated Plans.
    - **Variant**:
        - A specific model of a target, OAR, or other structure. A physician may provide an initial target contour and a treatment plan generated using this information. The physician may later (using the same CT image set) provide a revised target contour. Rather than import this revision as a new structure or override the original, you may specify this new contour as a variant of the original. Each contour may have only a single "active" variant and the plan will automatically update based on the selection of the active variant. However, in some cases it is not desirable to update the plan, so the user may

also choose to lock the plan and simply recompute DVH and other volume based statistics based on the new active variant geometry. In either case, variants can be used to streamline workflows and prevent accidental misuse of out-dated contours.

- **Plan**:
  - A detailed model of a proton therapy treatment. Most aspects of the patient planning information are stored here (e.g. Beams, Fraction Groups, Optimization Information, and Dose Results). A Plan will specify the portion of the Prescription it should meet and physicians will publish (approve) a Plan to indicate it is ready to proceed to QA and (if successful) on to actual patient treatment. There should be only one "published" Plan per Prescription. Plans may optionally contain a fluence override vector that will be used in place of the actual optimized fluence results from the plan (note there are no UI tools to add such overrides and they must be added via user controlled scripts).

Structures in the Data Model

There are multiple levels that various structures can live at. Each level and structure type will effect how the structure will relate to the plan. Refer to the Structure Data Model Guide for more details.

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Last update: **2021/02/12 20:16**

Planning App User Guide

Overview

The .decimal Astroid Planning App is used for treatment planning of proton radiation therapy treatments. The Astroid Planning App is an interactive end user application that leverages the existing .decimal Dosimetry App functions for device creation, dose calculation, and optimization to facilitate efficient development of proton radiation treatment plans.

Purpose

The purpose of this document is to provide guidance on the setup, access, and usage of the Astroid Planning App.

Getting Started

Proper use of this software is critical to safe and effective treatment of patients using plans generated by this application. Users are expected to read and understand this complete User Guide including the Instructions for Use, which outlines the general usage principles and limitations of the Astroid Planning App. Users must read and understand these instructions before operating the system for clinical use. Refer to each section below for complete details:

- **Instructions for Use**
    - Overview and Indications for Use
    - User Responsibilities
    - Warning
    - Intended Use
    - User Profile
    - Product Features
    - Data Model

Precautions

It is the responsibility of those utilizing this application to ensure all that all usages of this product relating to patient treatments are performed by trained and qualified personnel only and that such personnel is aware that the quality of any generated treatment plans is highly dependent on the quality and correctness of the input data; therefore if any questions or uncertainties exist regarding the quality, units, or identification of input data arise, they must be investigated and resolved before the data are used.

Initial Setup

Once Astroid has been purchased, Astroid staff will assist with beam model creation, software installation, and user training. Users will be generally be trained at two separate levels, system administrators and end users. System administrators will be setup with appropriate access and tools for managing software including both the local and cloud resources. End users will be primarily trained on the details of generating high-quality treatment plans using the local client portion of the application suite. The beam modeling and equipment setup processes are explained more fully in the Dosimetry App Commissioning Guide.

Installation

The Astroid Planning App includes both a local User Client and a cloud-based calculation provider, therefore, there are specific requirements on computers in which the local client application can be installed. Please see the System Requirements page for details.

Site Settings and Defaults

The astroid Planning App provides a RKS record for specifying site level configurations and defaults. The RKS entry exists at the root level of the realm for which the app is installed. The record holds a site_info, whose definition can be viewed at the astroid Manifest Documentation site. An empty

sample json version

of the site_info is provided.

To update the site_info RKS record, perform the following steps. Note: you must have Thinknode *"iam:buckets:unlockEntries"* policy permissions in order to unlock this RKS record to update it.

1. Using the Thinknode Client or manual RKS GET routes view the RKS records for the realm in which you wish to update the site_info
2. Find, or create if it's missing, the RKS record named "site_info" at the root level of the RKS entries
3. Unlock the site_info RKS record using the Thinknode PUT /rks/:id/unlock route
4. Edit the site_info by either:
    1. Editing in place the site_info data using the Thinknode Client or
    2. Post new site_info data as an immutable object and update the Reference ID for the RKS entry
5. Lock the site_info RKS record using the Thinknode PUT /rks/:id/lock route to prevent unrestricted changes.

Site Facility Model

The site_info for the astroid Planning App references the astroid Dosimetry App machine model. This model must be posted and referenced from within the site_info rks record.

Keyboard and Mouse Controls

Astroid utilizes keyboard shortcuts to help streamline many commonly used functions and display controls. A complete listing of these shortcuts along with a full description of the mouse controls is located at the Keyboard and Mouse Controls page.

Tutorials

Task Descriptions

The following task descriptions are thorough guides providing complete information about each task within the Astroid Planning Application.

- Launching the Astroid Planning App
- Uploading DICOM Patient Files
- Importing Patient Data
- Courses, Intents, and Directives
- Patient Models
- Creating a Plan
    - Structures
    - Dose Grid
    - Proton Beams
        - Defining an Aperture
        - Defining a Range Compensator
    - Astroid Optimization (PBS)
        - PBS Fraction Groups
        - Defining Constraints
        - Feasibility & Constraints
        - Setting Objectives
        - Running the Optimizer
        - Dose Normalization
        - Navigating the Solutions
    - Beam Delivery (SOBP)
        - SOBP Fraction Groups
    - Using the Plan History
    - Publishing a Plan
- Plan Templates
- Exporting a Plan

- More coming soon …

End-to-End (Plan) Walkthroughs

The following walkthroughs will take you through the process of creating complete treatment plans in the

Astroid Planning App. They provide detailed steps so that any user can begin using the software. Each guide covers a specific type of treatment plan, and although some walkthroughs share certain steps, each has been written as a self-contained unit so that you may begin with whatever guide is the most useful.

- Prostate Plan Walkthrough

System Usage

Improper System Usage

When using the Astroid Planning App, as with any complex program, there is the potential for misuse. The various Astroid Apps comprise a suite of radiotherapy treatment planning tools that are intended to be used by experienced and knowledgeable professionals working in the field of radiation therapy.

Known Application Limitations

Below are listed the known application limitations, defects, or inconsistencies.

General

1. Astroid uses DICOM patient space coordinates for all slice and 3D views and IEC 61217 coordinate systems for BEV (other options, such as machine based coordinate systems are NOT available at this time)
2. If a user's computer is abruptly shut down (e.g. computer crash or power failure) while the Astroid Planning App has a plan open, there is a potential for the user's local data cache index file to become corrupted. If this happens, generally the Planning App will automatically close (crash) whenever the user tries to open the plan that was active at the time of crash. In order to fix this, the user must close the Planning App and delete the entire cache folder. The default directory location for this folder should be C:\Users\All Users\Astroid2\cache. If the location has been changed, the new location can be found within the Planning App from the *View–>Settings* menu.
3. If a user starts a calculation using the calculation status UI (e.g.: feasibility or MCO) and is outside the block the interface is in when the calculation finishes, the status of the calculation will remain "calculating". Manually refreshing data (pressing F5) or re-launching the application resolves this issue.
   - This issue may also apply to other requests and calculations in the application too
4. Treatment plans store an optional fluence override vector which will be used instead of the optimization fluence results if present. These overrides must be added via scripts outside the Planning App UI. If an override is present in a plan the Planning App UI becomes mostly read-only to limit the potential for changes that could invalidate the fluence override. However there are no hard stops to ensure that the fluence override vectors are properly sized for the plan at hand, so users must ensure properly sized fluence vectors are set in their scripts.

DICOM Upload

1. The Uploads block must remain open while uploading DICOM files.

DICOM Export

1. Computed treatment plan dose is required prior to users being able to export DICOM files.
   - Note: Users may still be able to attempt to export DICOM files from the user interface, but may encounter errors if their plan does not have, or is unable to, compute dose.
2. DICOM Export of CT and SS files searches the RKS for the CT image record, therefore modifying the RKS record of the CT images can cause changes to the exported data even on an approved plan (deleting the record will prevent export of CT and SS altogether)

Importing

1. When importing a new patient, the default physician will be set from the DICOM file. When this physician selection is changed, either during import or later in the Patient Overview, there is no way to re-select the original from DICOM physician.

Plan Templates

1. Plan templates are unable to be edited and/or removed from within the Planning App without manually manipulating the RKS record.
2. All referenced and used structures in the original plan template must exist in the new patient model for which the plan template is being used.

Structures

1. When changing a structure type from a TARGET, whether at the Patient Model or Plan level, if that structure was an existing optimization constraint or objective with maximize options selected, those options will continue to be selected and will unable to be changed in the UI. They can be viewed in the optimization constraint and objective summaries, but will not be editable unless the structure type is changed back to TARGET.
   1. This can result in you having constraints or objectives that might not be ideal for this type of structure. Always double check the constraint/objective summaries if you need to change a structure type from TARGET after you've added optimization parameters to that structure.
2. Structures that are expanded in the axis of the CT image slices will have the expansion distance limited by the CT image spacing. So the expansion distance may appear to be an incorrect distance.
3. When creating a new target for a PBS beam via the Create subtask from the Geometric Target drop down, you are able to create a non target structure and have it be selected in this drop down. This is only possible when the Create subtask automatically populates the dropdown upon finishing, and you will not be able to select this target manually if you change the selection.

Facility Model

1. When multiple machines are defined in the facility model each room must have a unique name within the entire facility model. The treatment_plan references a treatment_room by it's name and assumes this name will only exist one time in the facility model.

Machine/Patient Collision

1. Astroid does not detect possible collisions between the patient and snout or the treatment table and snout. It is the users responsibility to ensure that there is enough distance between the patient/table and the snout so as to avoid collisions.

SOBP Patch Fields

1. For SOBP plans with patch fields, dose overlap at the patch junction may result in a maximum dose that exceeds the limits of the isobands and DHV displays
2. If a patch field is added to an existing thru-beam that's already in a fraction group, the thru-beam must be removed and re-added to the fraction group for the patch field to be included in the fraction group's beam list.

See Thinknode Errors for common problems that can occur during usage of the Planning app.

Should you discover or suspect any additional errors or limitations not noted above, please alert the .decimal Astroid Planning App development team by providing creating a ticket at dotdecimal.freshdesk.com including details of your concerns and steps to reproduce the issue. All concerns will be addressed as quickly as possible and follow up with the submitter will occur throughout the inquiry and correction process.

ResultsAPI

The ResultsAPI is provided to facilitate a controlled and consistent means for accessing necessary treatment plan details and information. The ResultsAPI is most frequently used by customers wishing to develop custom treatment plan reports for clinical patients. From the ResultsAPI treatment plan data can be accessed, including (but not limited to): patient geometries, prescriptions, beam information, spot placements, and plan dose results. It should be pointed out that when users generate custom plan reports they must include an indication of the coordinate system in which any position information is being displayed and users should be reminded that all ResultsAPI position data is provided in either DICOM Patient or IEC 61217 Beam coordinate systems, as appropriate, at this time. Plan reports must also include a list of any density reassignments that were used in the plan.

Most Planning ResultsAPI functions must be called using Thinknode meta requests. Because of this added complexity, an example function call is provided to aid in end user understanding of proper usage.

Please refer to the Planning App ResultsAPI Guide for a more detailed look at explanation, usages, and examples of the Planning App ResultsAPI.

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Last update: **2021/02/12 20:12**

Tutorials

Launching Astroid

The Astroid *Launcher* will house the various applications that will be used as part of the Astroid Treatment Planning system. Any updates to these applications will automatically be deployed to the *Launcher*. The user will be notified that there is an update or a new version that will need installation once they have chosen an application. This will ensure that cloud version of Launcher and the local version of Launcher remain synchronized. Use the following steps to open the *Launcher* and launch the Astroid Planning App:

1. Open the *Launcher*
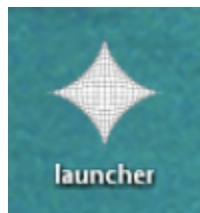
2. Sign in using your account, user name and password
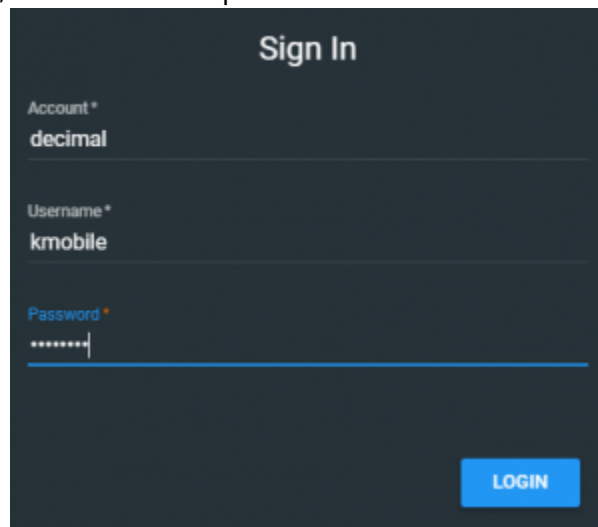
3. Click the blue *Login* button
4. Select your realm from the list of available realms
5. From the left side tool bar select the application you would like to launch
6. Click the blue *Launch* button
    1. If there is an updated version of this application, the *Launch* button will not appear and instead an *Install* button will be available. Click this to allow the latest version to install. After the latest version is installed, the blue button will revert back to *Launch*, which you can now click
7. This will open the Astroid Planning application and bring you directly to the main patient search screen
8. You may now proceed with opening a current patient or importing a new patient

2017/01/11 20:35

Uploading DICOM Patient Files

The Astroid Planning App stores a list of DICOM files (only CT Image Set and Structure Set files are supported at this time) that are available and ready for Import. There are several approaches that can be used to upload DICOM files into this list.

DICOM Receiver Service

For clinical users, a DICOM receiver is generally installed, allowing for direct exporting from contouring software or other planning systems for use within Astroid. In such cases, this DICOM receiver service will be pre-configured to upload the incoming files directly to Thinknode and will also create the records necessary for the DICOM files to be populated into the Astroid Planning App list of available Imports.

Uploading using the Planning App

DICOM files can also be uploaded directly from the Astroid Planning App. The steps below describe the process in detail.

1. Open the Launcher and choose the appropriate realm and application to work in
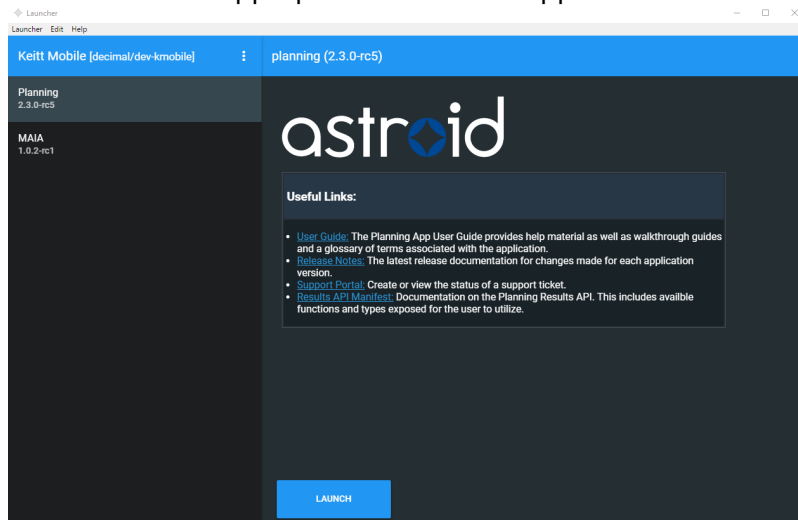
2. Choose the *Imports* block and click the blue Browse button in the *Upload Files* sub-block
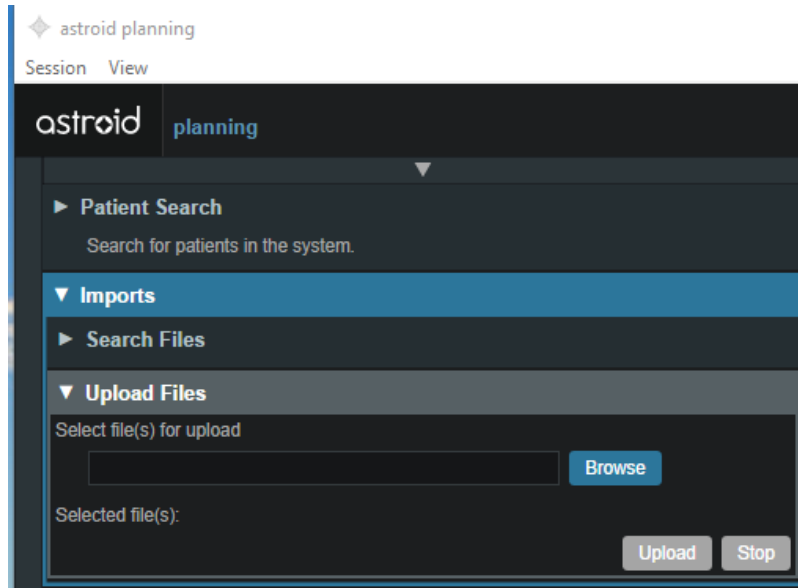
3. Navigate to the directory where the DICOM image and structure set files are stored and click Ok
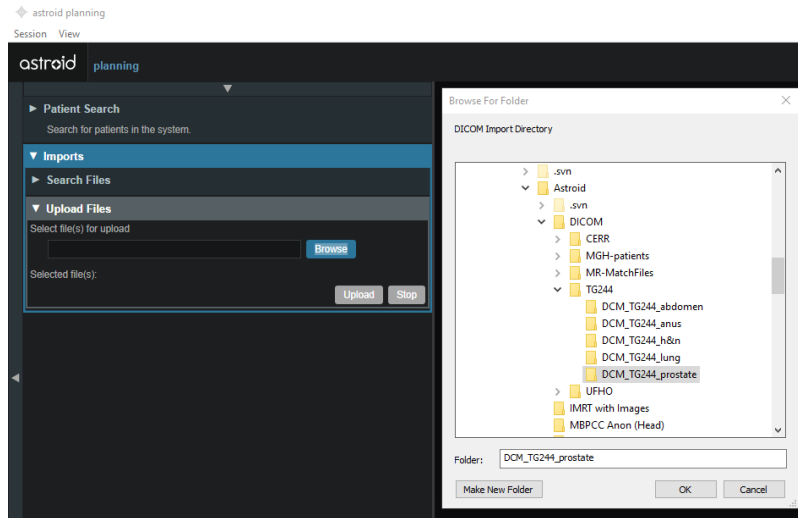
   1. All DICOM files found in the selected directory will populate in the list field

4. If the file list appears correct, click the blue Upload button in the bottom right corner to start the Upload
   1. This may take a couple of minutes to complete
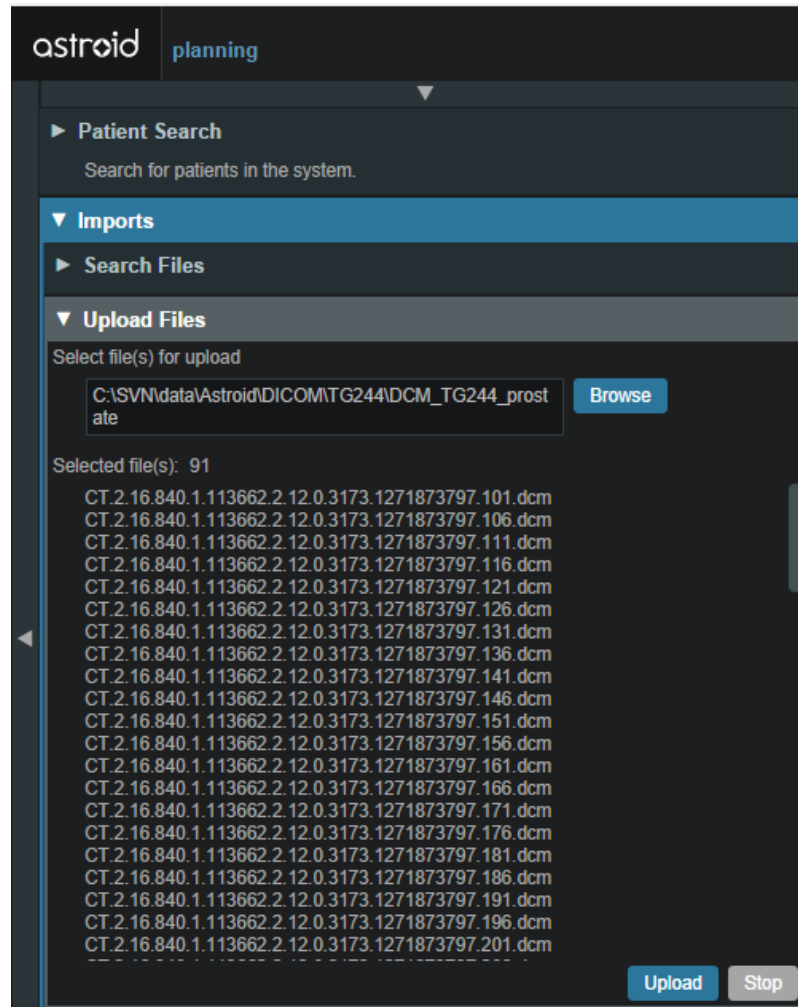
5. Once the file(s) finished uploading they will appear in the list of available files, click back on the *Search Files* sub-block to return to the list of available files

Bulk Importing using Python

Note: This section requires the user to be familiar with python and the existing .decimal python libraries.

Importing a new patient into the Planning App requires taking a local DICOM directory and posting each of the files through the Dicom App utilizing Thinknode. Each DICOM patient is posted to the Thinknode ISS and an entry is then added to the thinknode RKS that allows the Planning App to see that a new patient has been added. The steps below explain how to upload patient DICOM files using the open source python Astroid Script Library.

1. From the .decimal GitHub repository open and edit the post_dicom_patient_rks.py python file.
2. Ensure the thinknode.cfg file is set appropriately for your user, account, and realm.
3. Edit the following line to point to the directory in which the DICOM patient files are located (note: all DICOM files in this directory will be uploaded):

```python
# Post patient data into ISS
obj_list_id = dicom.make_dicom_object_from_dir(iam, 'F:/Datasets/demo-patient/prostate')
```

4. Run the script and allow the patient to upload to thinknode ISS. After the DICOM patient files are uploaded to ISS, an RKS entry will be created for the Planning App to recognize it as a DICOM file that is available for import.

2016/08/17 12:55

Importing Patient Data

Now that a patient has been uploaded from DICOM, the Planning App should recognize that new patient files are available to import into a Planning patient.

1. Open the Astroid Launcher and launch the Planning App from your realm
2. Once Astroid Planning starts, click on the Imports Block in the task control pane on the left side
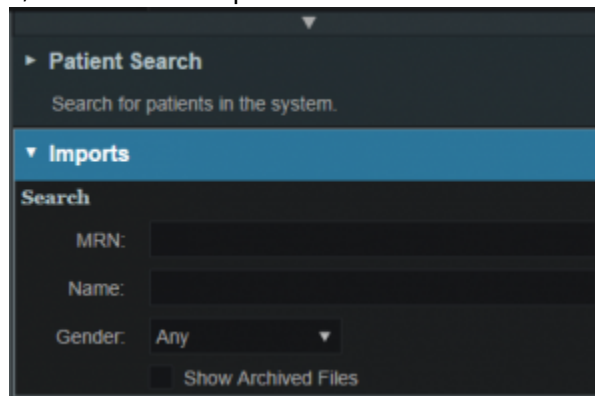
3. Select the CT image set from the list of available files for import
4. Ensure that the MRN is correct
5. Click the *Create Patient* button to start the import process
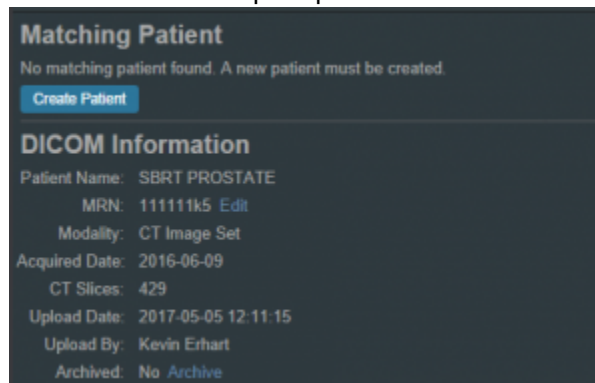
6. Ensure that the date and time displayed in Astroid matched the current date and time in the current Windows OS.
7. Fill in the requested Patient Intent, taking care to select the appropriate *Treatment Site* as this selection contains the template information that will be used during structure set import
8. Select the appropriate HU to RSP curve (as shown below)
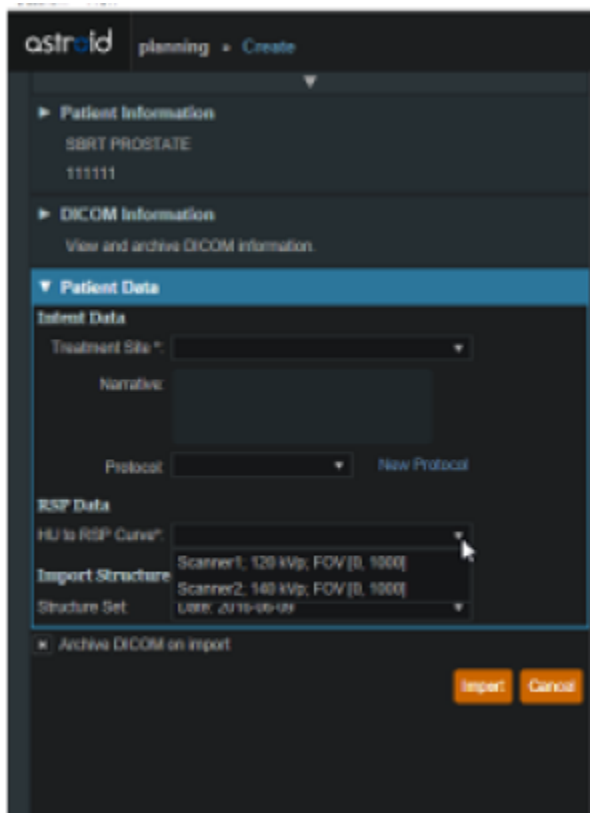
9. The corresponding structure set (SS) file to import with these images will automatically be selected. The structures will show up below the Patient Data box in the Import structures box (note that the available choices will be automatically filtered based on the structure set DICOM UID information)

1. The structures associated with the data set will be seen in a list of the available structures
2. Here you may choose whether or not to import each structure by checking or unchecking the box beside each structure name
3. Matched, Assigned, and Custom structures are designated with corresponding tags at the end of the structure name in the structure list
    1. You may only edit structures that are shown as *Custom*, which indicates the name did not exactly match a course structure from the *Treatment Site* template selected above
    2. For all custom structures, the type is by default set to the value from the DICOM file. If there is no type specified in the DICOM file the type will be set to "Other", unless it contains the letters "TV" (as in PTV or CTV), in which case it is assigned the type of "Target"; the type may be changed here if needed
    3. Alternatively you may *Assign* a *Custom* structure to a course level template structure using the provided drop down menu (this is useful when structure names contain typos or contour names otherwise do not match your standard site protocols)
        1. Assigning a custom structure to a defined course structure will result in the imported structure inheriting all the predefined structure properties (e.g. name, type, color)
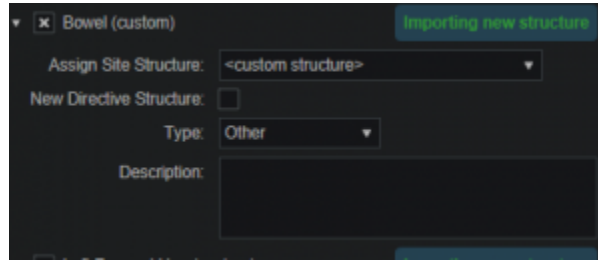
10. Once all structures have been selected, assigned, and edited as needed, click the *Import* button to create the patient and import the CT Images and Structures into it
11. The patient is now created and all available data has been imported
12. Click on the *Back to Import* button to return back to the *Imports* task

Structures in the Data Model

There are multiple levels that various structures can live at. Each level and structure type will effect how the structure will relate to the plan. Refer to the Structure Data Model Guide for more details.

2016/08/17 12:56

Courses

Overview

The Astroid patient data model uses a hierarchy of items to model the real world workflow patterns of the radiotherapy treatment process. Please refer to the **Heirarchy (Data Model) page** if you are not familiar with these concepts.

During patient creation (i.e. Importing) a patient record is created containing a *Course* and a *Patient Model*. During Import the required data for the Course and Patient Model are entered, however, the Course remains incomplete. The Course will still require physician directive information including the breakdown of the treatment *Prescriptions* and (optionally) the specification of *Clinical Goals*. Before creating a *Plan* this information must be entered. Once the Prescription is complete, plans can be created. The following sections provide a walk through for completing the *Course* information.

Prescriptions are cumulative. For example: when adding a second prescription, it is assumed that the highest dose from the first Rx has already been delivered to the target for the second prescription. Therefore, the total dose to all targets in the second prescription will have the first prescription's highest dose added.

Completing the Course Prescription

1. From the *Patient list*, select a patient to be opened by clicking the patient row
2. The patient will open to the *patient overview* task and a message will appear telling the user to complete the Prescription information
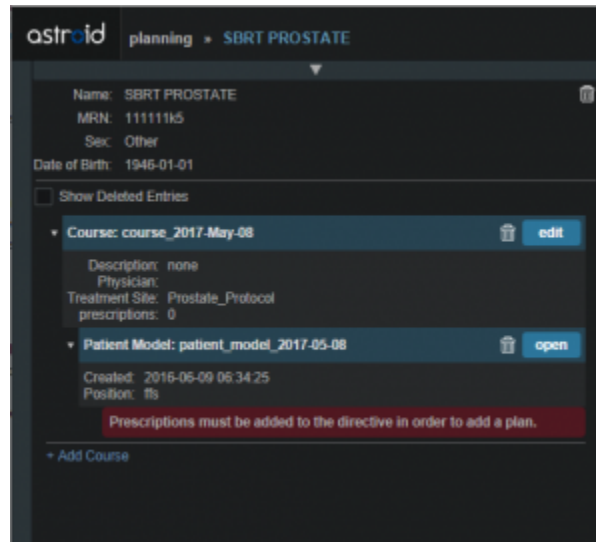
3. The Prescription information is part of the Course, which can be edited by clicking on the blue *edit* button beside the Course label in the patient overview
4. The *Course* Prescription information is **mandatory** to fill out in order to proceed with planning and at a minimum one Prescription must be created (Clinical Goals are optional)
5. The *Course* contains some basic information as well as two blocks of data: *Clinical Goals* and *Prescriptions*
6. *Clinical Goals* are used fill in the "goals" (objectives) the physician would like to see achieved by the plan
    1. To add a goal, simply select click *Add Structure* and select a desired structure (the choices in the structure drop down will be set by the treatment site template) to which goals should be added
    2. The user can create goals for tumor volumes as well as Organs at Risk (OAR) and can specify minimum dose, maximum dose, mean dose, and volume based (DVH) goal types
    3. The *Clinical Goals* will be used for reporting purposes to describe the physician's intent for the treatment; these do not affect the calculation or plan directly
7. The second major part of the *Course* are the *Prescriptions*
    1. This is where the user will fill in the number of fractions and the prescription dose that specified by the physician
    2. Note that a prescription **must** be created in order to start the planning process
8. Click *New Prescription* under *Prescriptions* to create a new empty phase
    1. The *Prescription* label and description are free text fields that the user can enter to help identify a particular phase as needed
        1. If the structure chosen is not contained within the patient model a yellow triangle will appear next to the structure chosen alerting the user
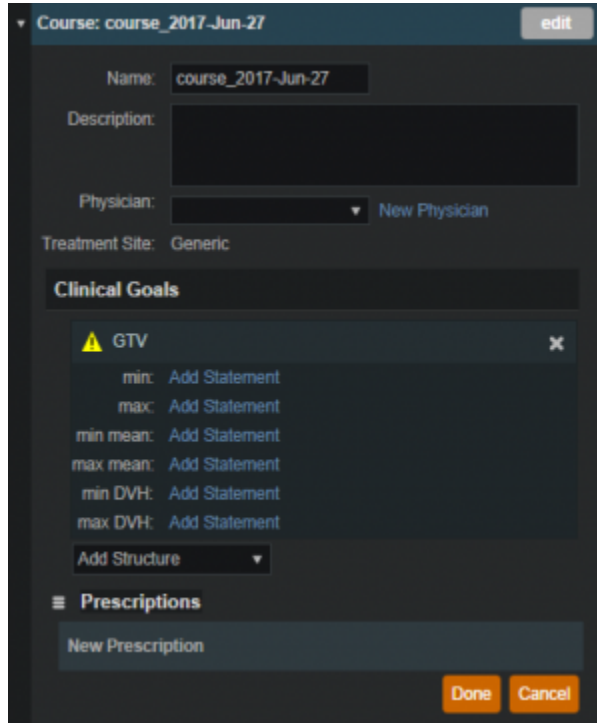
2. A color may be selected for the Phase to aid in identification as well
3. The number of fractions to be treated should entered and at least one *Prescription* value must be added (the choices available in the structure drop down will be only the targets from the selected treatment site template)
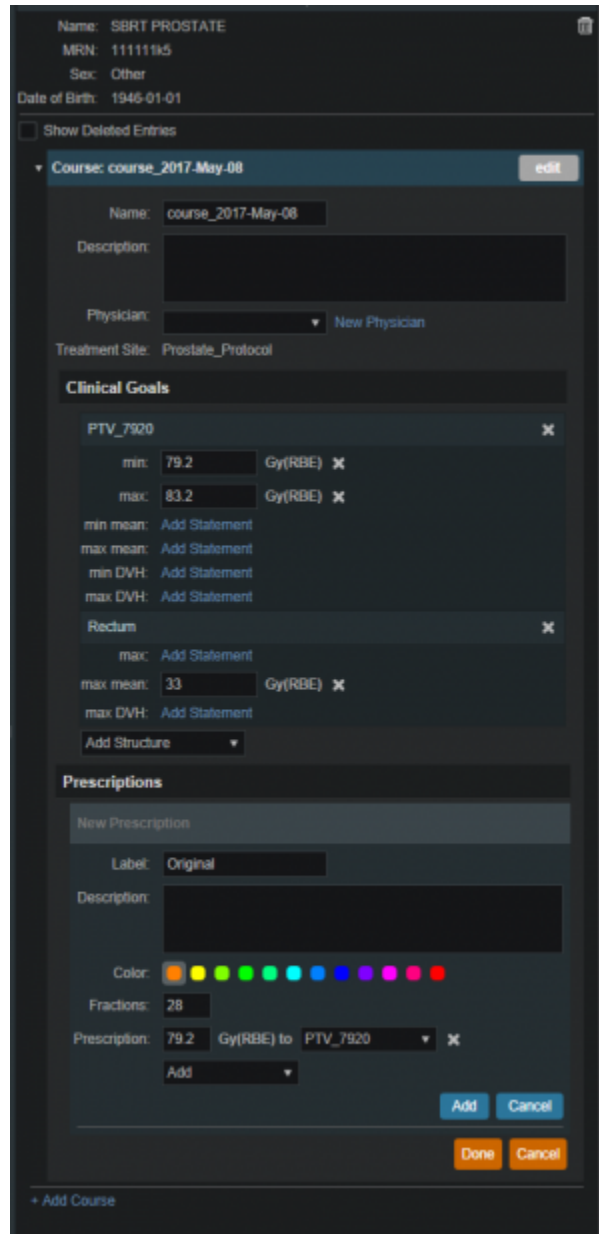
4. Once all Prescription information has been entered, click the blue *Add* button to complete the Prescription
9. Additional prescriptions may be added at this point if needed (for example, for a treatment needing a base treatment and a boost)
10. The *Course* should now be complete
    1. Click on the *Done* button to return back to the *Patient Overview*

2017/01/19 22:23

Patient Models

Once the Course has been completed the next block will be the Patient Model. The Patient Model contains a single CT image set and all contour variants (targets and organs at risk) associated with these images.

About Patient Models

- **Patient Model**: captures the state (anatomy) of a patient at a certain point in time. Each Patient Models contains a single Image Set (typically CT) and all contour (structure) variants associated with these images. Each unique Image Set imported into the patient should produce a new Patient Model. Each unique structure set imported into the Patient Models should produce new contour variants for each unique contour. Each contour may have only a single "active" variant and the plan will automatically update based on the selection of the active variant.
- **Variant**: A specific model of a target, OAR, or other structure. A physician may provide an initial target contour and a treatment plan might be generated using this information. The physician may later (using the same CT image set) provide a revised target contour. Rather than import this revision as a new structure or override the original, you may specify this new contour as a variant of the original and the plan will automatically update based on the selection of this new active variant (note each contour/structure may have one or many variants, but only a single variant can be designated as "active").

Structure Data Model

There are multiple levels that various structures can live at. Each level will effect how the structure will relate to the plan.

> **Note:**
>
> - The assignment of structure type will determine the types of constraints or objectives you can put on the structure.
> - Only structures with a Type of Target can be used as Beam Targets
> - Site level, Course level and Custom structures can be shared within plans on the same patient
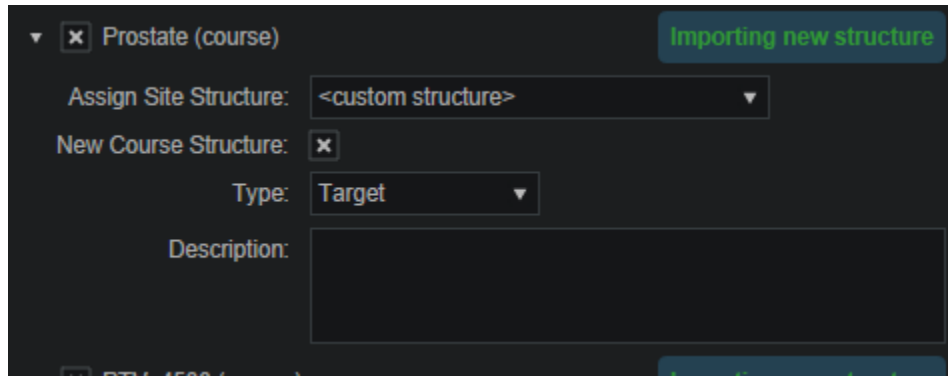
Site Level Structures

Site level structures are predefined templated structures. The user is not allowed to edit any aspect of a Site Level structure. Site level structures may be used for prescriptions as long as they have been designated as a Target.

Course Level Structures

Course level structures are not predefined templated structures (Site Level Structures). Course level structures may have certain properties edited within the planning user interface (e.g.: their type). A structure may be assigned as a Course level structure by choosing the box "New Course Structure"

option at the time of import for any structure that does not automatically match a Site Level Structure.

Structures that have been changed to Course level will have be designated as such by the word "course" appearing in parentheses beside the structure name during import. This is useful when a structure was misnamed during the contouring process. Course level structures that have been designated as Target structures can also be used for prescriptions. Any structure with TV as part of its name will automatically be designated as a Course Level structure.

Custom Structures

Custom structures show up at the Patient Model level. These are structures that were not part of the templated structures nor assigned as a Course Level structure. The user has the option to edit the properties of a custom structure from within the Patient Model task.
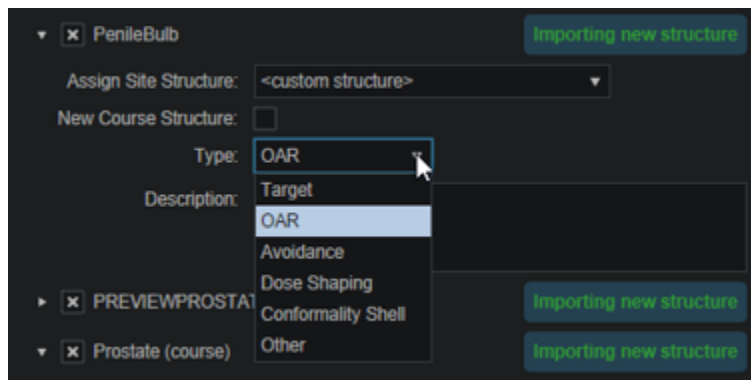
Plan Level Structures

Plan level structures are structures created with the Astroid TPS. These structures are derived from existing structures (e.g.: expansions, combinations). See Patient Geometry on how these are created.

Structure Types When Used in Optimization Constraints and Objectives

The structures type determines the options available to the user when specifying constraints and objectives for the treatment plan optimization (refer to Optimization Constraints and Optimization Objectives for definitions of Constraints and Objectives). Below explains the structure types and options available for each type during optimization:
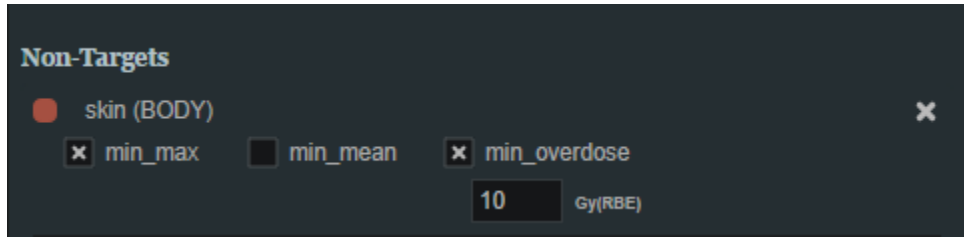
Non-Target Structures

For structure types that are not *Target* or *Other* the user only has the ability to set constraints and objectives that drive the dose **downward**.

- **Constraints**: only maximum and maximum mean dose settings can be added to the structure.
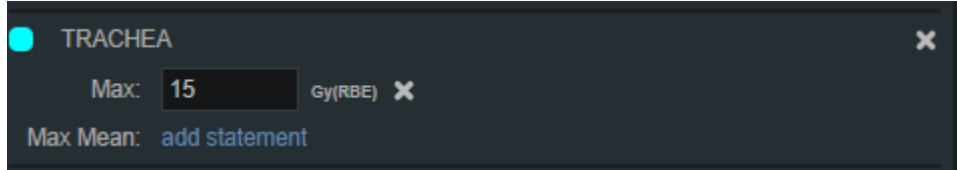
- **Objectives**: only minimizing objectives (minimize the maximum, minimize the mean, and minimize the overdose) can be added to the structure.


Target and Other Structures

For structure types that are *Targets* and *Other* the user has the ability to set constraints and objectives that drive the dose **upward** and **downward**.

- **Constraints**: Both maximum and minimum dose and mean dose constraints can be added to the structure.
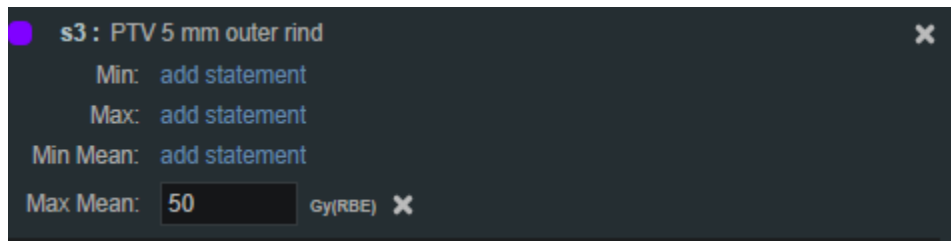

- **Objectives**: Both minimizing and maximizing dose objectives cab be added to the structure.
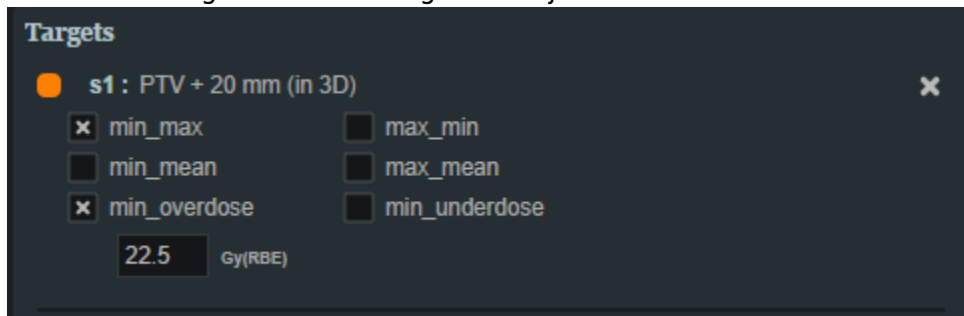
Working with Patient Models

Within Astroid the planner has the ability to view the Patient Model details and edit certain structures in a limited capacity.

1. A Patient Model contains data relating to the image set such as the number of slices, who imported the image set, the import date and the UID.
2. A Patient Model also contains a list of the structures that were imported.
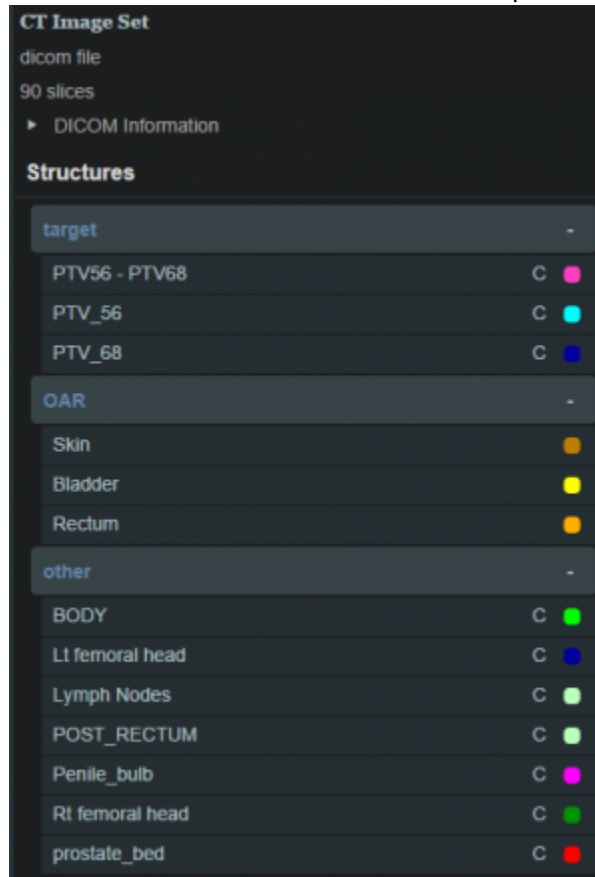
3. The user may choose to set the active variant for any structure present in the snapshot.
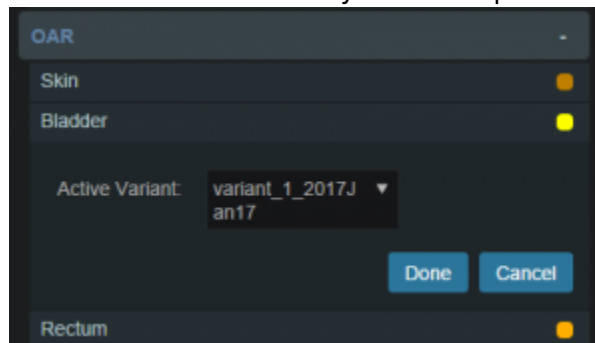

4. Structures not defined in the site config (i.e. custom structures) are denoted with a "c" beside it. These structures have the ability to be edited in a limited capacity. The planner may choose to change the structure variant, color, and structure type. The planner may also choose to enter any notes that may be helpful at this point.
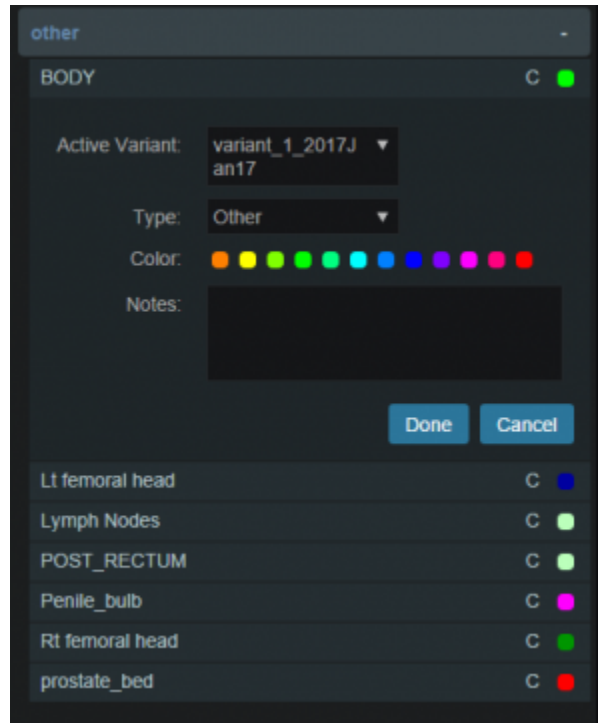
2016/08/17 12:56

Creating a Plan

1. The point has now been reached where a *Plan* can be created
2. Click on the blue *Add Plan* link under the *Patient Model* to create a new plan
   1. In the box that opens the user should name the plan and add any description they may want
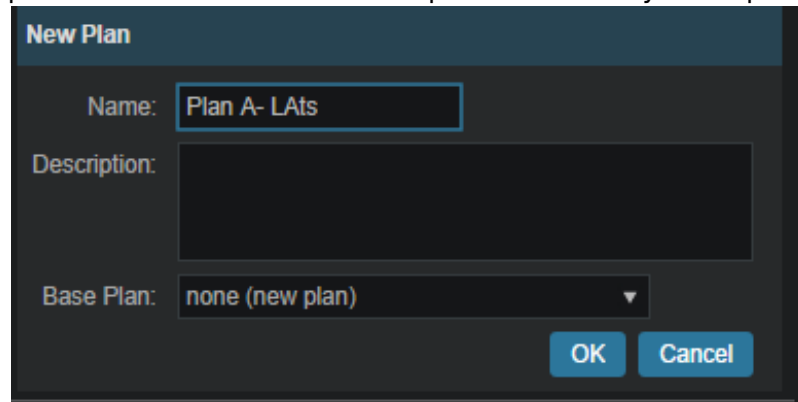
    2. Note that the *Base Plan* option is used to specify whether an empty plan should be created or if the new plan should be pre-filled using the selected *Plan Template* (details on *Plan Templates* can be found here)
    3. Click on the blue *OK* button when finished and the *Plan* has been created
3. Open the plan and begin the planning process by clicking on the blue *Open* button next to the new plan
    1. Note that users are free to have as many plans as desired within a the *Patient Model* and each Plan will specify which portion of the Course Prescriptions it is attempting to implement

2016/08/17 12:57

Patient Geometry

Patient / External Structure

The Patient or External structure is one of key importance in Astroid. This structure is used to define the extents of the dose calculation process. This includes the extents of the dose grid, as well as useful area of the CT images for the purposes of Relative Stopping Power conversion. Planners should be aware that all area outside of the External contour is considered to have an RSP value of 0.001 (air). As a result please ensure that any devices that need to be considered in the calculation such as: patient immobilization or positioning devices or the couch are contoured as part the external contour if they will be present during treatment and may impact the delivery beams. Please note in the example below how the planner included the head holder, mask, and S-frame as part of the External contour so that all of these devices will be included in the dose calculations. The couch was safely excluded in this example because no "through couch" beams were going to be used in this treatment. This "air" override is applied **BEFORE** any manual user overrides are applied.
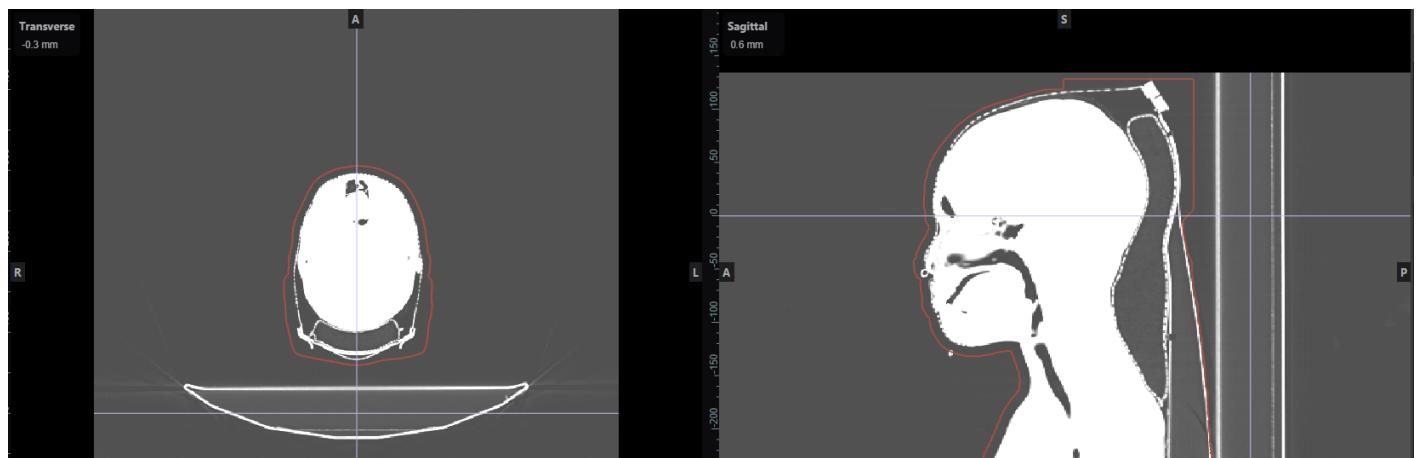
Structures

Within Astroid the planner has the ability to create additional structures that may be needed when building a treatment plan. The Astroid Planning App allows for new structure creation using modifications of existing structures only. These modifications include boolean combinations, expansions/contractions, rinds, and clipping (i.e. splitting by a plane).

General Structure Options

- **Type**: Set the type of the new structure (Target, OAR, Avoidance, etc)
    - Type may be left blank to allow it to be "inherited" from the type of the base structure
- **Color**: Display color for the new structure
- **Description**: Optional, user specified text describing the new structure

Structure Geometry Types

The following is a detailed explanation of each of the structure geometry functions that may be used to create or edit structures within Astroid.

Combination

Allows for the combination of two or more structures using set (boolean) operations. The planner must choose which type of set operation they desire to create the new structure.
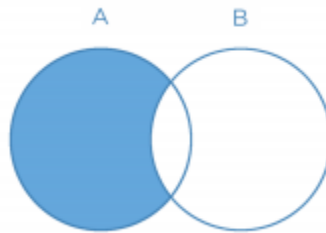

- **Union** - Combine two or more structures. The resulting new structure will contain the points that are within **ANY** of the selected structures. Structures are selected from a series of simple drop down menus. Refer to this union example for a sample of a union structure being created.
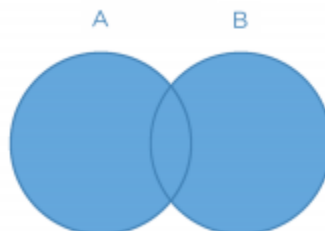

- **Intersection** - Use only the overlap of two or more structures. The resulting new structure will include only the points that are in **ALL** of the selected structures. Structures are selected from a series of simple drop down menus. Refer to this intersection example for a sample of a intersection structure being created.
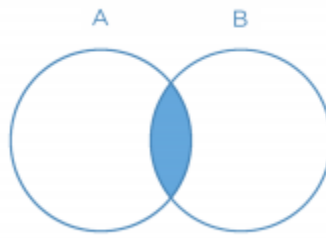
- **Difference** - Subtract one or more structures from a base structure. The resulting new structure will include the points that are in the first structure but not the others. The base structure is selected from the first drop down. The structures to subtract are then selected from the next series of simple drop down menus. Refer to this difference example for a sample of a difference structure being created.

- **XOR** (Exclusive OR) - Combine two or more structures with exclusivity. The resulting new structure will include areas that are within an odd number of structures only and will exclude areas that are within an even number of structures. Two or more structures need to be chosen from the drop down to create the new structure. The shaded areas in the examples below show the new structure and demonstrate the XOR functionality. The non-shaded areas would be excluded from the new structure.
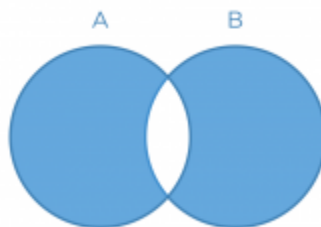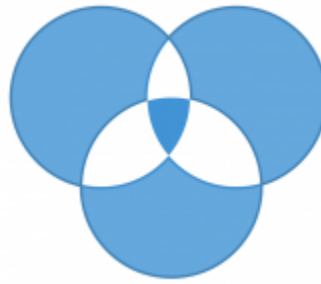
Expansion

Allows for creation of a new structure as an expansion or contraction of an existing structure. The base structure is selected from a simple drop down menu. An expansion is performed by entering a positive number for the expansion amount. Conversely, a contraction is performed by entering a negative number for the expansion amount. Structures may be expranded in two dimensions (structure will only expand/contract within its original slice planes) or three dimensions (structure will expand onto other slices as a true 3D expansion). Please note that the resulting structures are still slice based entities, therefore an expansion by an amount less than a single CT slice thickness may not result in the structure expanding out to additional slices. Refer to this expansion example for a sample of an expansion structure being created.
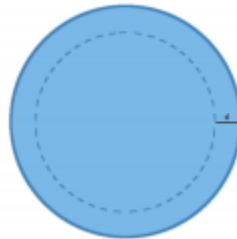
Rind

Allows for creation of a new structure as a thin ring around the surface of an existing structure. The base structure is selected from a simple drop down menu and then both an inner margin and outer margin are specified. Inner margin is the thickness of the ring toward the inside of the existing base structure. Outer margin is the thickness of the ring outside the existing base structure. Negative margins are not permitted, although zero is permitted for either value, allowing for the creation of one-directional rinds. It should also be noted that the resulting rind structures are still slice based entities, therefore rind thicknesses may not be fully uniform at the superior and inferior ends, as contours are limited by the CT slice positions. Refer to this rind example for a sample of a rind structure being created.
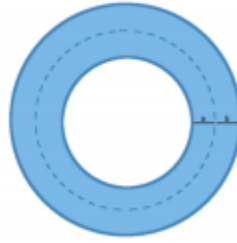
Clipped

Creates a new structure by splitting an existing structure by a user defined plane (and discarding the portion on the positive side of the plane). Any existing structure may be selected for splitting from a simple drop down menu. The split plane is defined by a single point and a normal vector pointing away from the portion of the structure that will be kept. The normal vector is defined by its three direction components XYZ and the point may be selected (or created) from the available point list menu. The XYZ normal vector directions refer to patient coordinates so that X is left-right, Y is ant-post, and Z is inf-sup (note: if the "wrong" side of the structure is removed, simply reverse the direction of the normal vector by changing the sign of each XYZ value). Refer to this clipping example of a clipped structure being created.
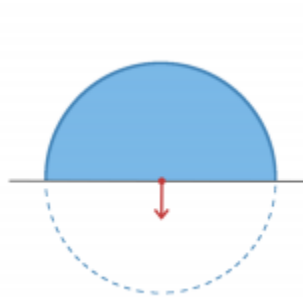

Working with Structures

This section walks the user through the creation of a of a new planning structure (an expansion structure is used herein for illustration purposes).

1. Open the *Patient Geometry* block
    1. This will open the patient *Structures* list
2. Click the *Create New Structure* button at the bottom of the list
3. Next, choose the *Type* of structure that should be created from the drop down menu at the top (or leave this blank to "inherent" the type from the base structure)

4. Change the *Color* and enter a *Description* if desired
5. Then, select the method of creation desired for the new structure: *Combination, Expansion, Rind*, or *Clipped* (see above for details about each method)
6. Choose the required structures and enter any other required information for this method and then click *Create* to complete the new structure
    1. For this expansion structure, the base structure and the expansion amount are all that is required
7. Once a structure has been created, it can be edited, cloned, or deleted by clicking on the structure and then clicking on the appropriate button
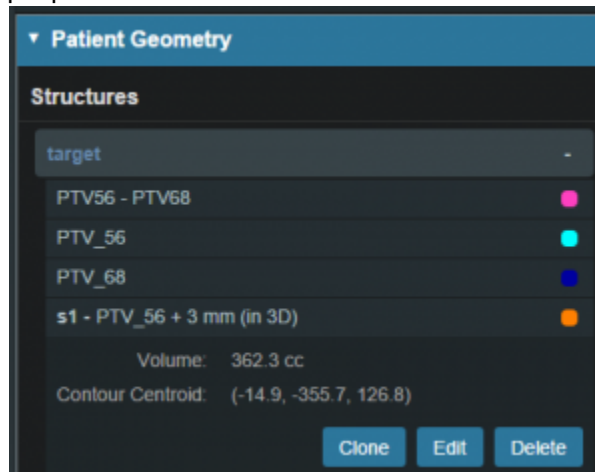
1. Note that when editing a structure, only simple options are immediately presented to the user, if further editing of the structure is needed, simply click on *more options* to open the full structure editing task which allows for editing of all structure options
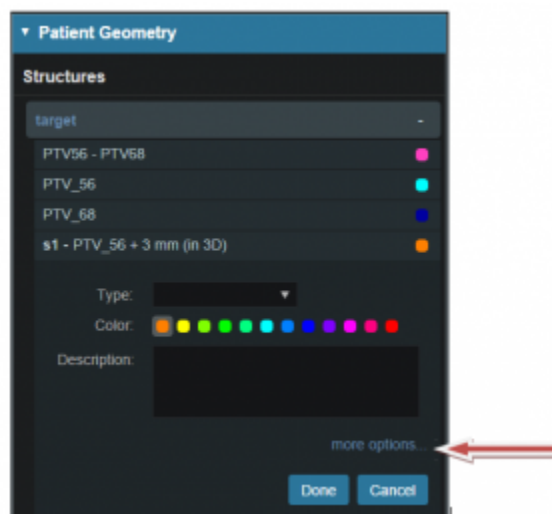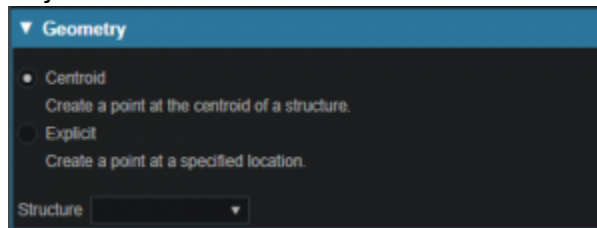
Points

Within Astroid the planner has the ability to create additional points that may be needed when building a treatment plan. These points include Isocenter, Point of Interest (POI) and Localization points.

General Point Options

- **Type**: Set the type of the new structure (Isocenter, POI and Localization)
  - Type may be left blank to allow it to be "inherited" from the type of the base structure
- **Color**: Display color for the new structure
- **Description**: Optional, user specified text describing the new structure

Working with Points

1. Open the *Patient Geometry* block
2. Click the *Create New Point* at the bottom of the *Patient Geometry* box
3. Next, choose the *Type* of point that should be created from the drop down menu at the top
4. Change the point *Color* and enter a *Description* if desired
5. Next choose the point location- *Centroid* or *Explicit*
   1. *Centroid* will place the point in the center of the structure chosen from the drop down list at the bottom of the Geometry box

   2. *Explicit* allows the user to place a point anywhere within the patient. The user will may enter the point coordinates in the XYZ axis (The XYZ normal vector directions refer to patient coordinates so that X is left-right, Y is ant-post, and Z is inf-sup) or may simply click and drag on a display to select the location of the point.
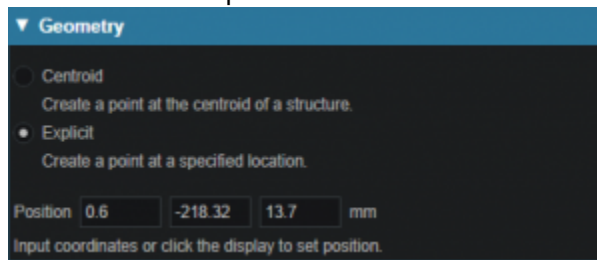
2017/06/19 21:03

RSP Image

The *RSP Image* block allows the user to choose (if not chosen during patient import) or change the HU

(Hounsfield Unit) to RSP (Relative Stopping Power) curve to use during the planning process. The user may also choose any density overrides for a particular structure at this point. An example of when to choose an override is the case of hip prosthesis. The user will need to know the RSP to be used for the chosen structure.

1. Open the *RSP Image* block
2. Choose the HU to RSP curve (if you wish to override the one chosen at import) from the dropdown list
3. If a structure needs a density to be overridden choose that structure from the *Add Override* dropdown list

4. Enter the RSP value for the chosen structure
5. Click *OK* when done

> The order in which density overrides are applied can often be important to users. The Planning App first applies the override outside the "external" structure and then applies any user added overrides in the order added by the user.

Note- Please see *patient_geometry* as to how RSP outside of the patient external contour is handled

2017/06/27 19:12

Dose Grid

Astroid utilizes a calculation grid that allows for local grid resolution to be specified on a per structure basis. This allows for improved optimizer performance in terms of both speed and resultant plan quality. A uniform sized base calculation grid is created over the entire patient structure. This base resolution can generally be set to a size much larger than the value needed for accurate clinical dose resolution. The user can then reduce the grid sizes in critical areas, generally the high gradient regions and target areas that require homogeneous dose, by assigning appropriate structures a smaller grid spacing value. A common configuration is to use a base resolution of 8mm, 4mm within critical OARs and the PTV/CTV and 2mm in a thin (rind) region surrounding the PTV. This provides sufficient dose information for the optimizer to maintain uniform dose to targets, drive down dose to OARs, and achieve steep dose fall at the boundaries of targets and healthy tissue. An example of constructing such a grid is given below.

1. Open the Calculation Grid block
   1. The default base resolution is set in the site specific configuration settings and is applied throughout the entire patient

2. This value may be adjusted if needed
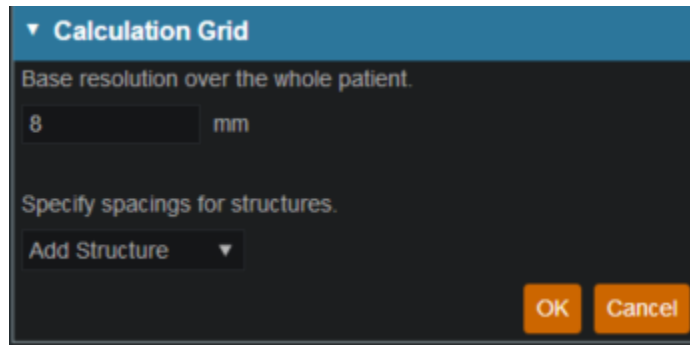
2. If you want to use a smaller grid in a target or OAR choose that structure from the dropdown and then specify the desired resolution
    1. Note that allowable resolutions are scaled down by powers of 2 from the base resolution by using the +/- on either side of the region spacing setting
    2. Notice the different size grid in the PTV and the patient
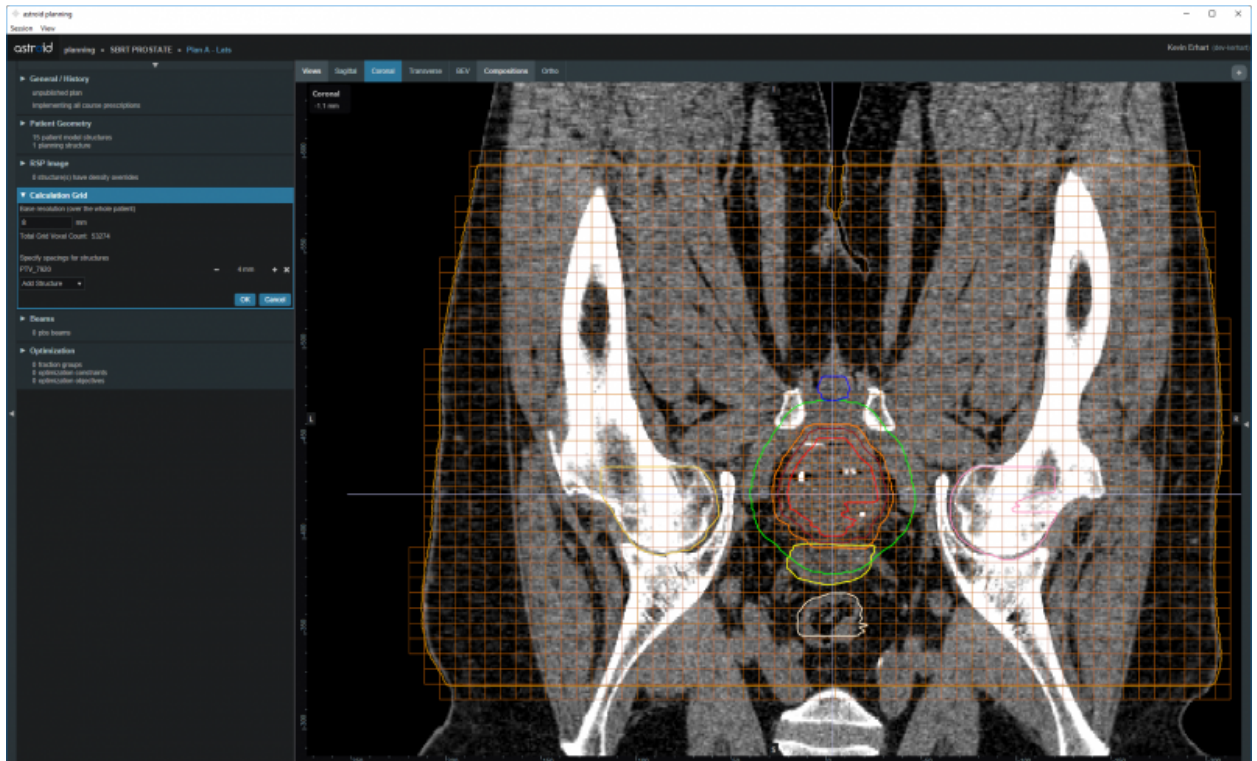
3. Additional structures with different resolutions may be added, such as for a high resolution dose-falloff region using a rind structure or very small OARs
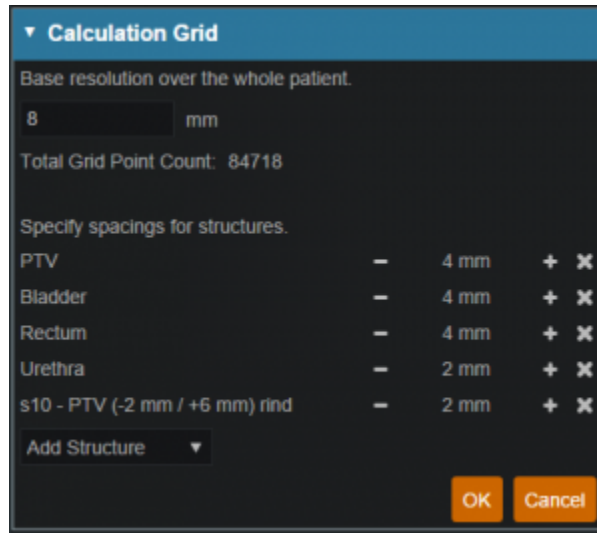
4. Once the appropriate regions and resolutions have been set, click *Ok* to save the calculation grid
   1. The Calculation Grid block can be revisited at any time to adjust the grid if needed

2016/08/17 12:58

Proton Beams

Defining treatment beams will be one of the most important tasks within the Astroid planning system. Defining appropriate beams will require users to use their knowledge and experience to properly select many of the parameters that define a treatment beam. These parameters include the target, geometry (isocenter, gantry and couch angles), beamline devices, air gap, and spot placement options. The *Beam* task utilizes a series of blocks to organize the beam creation process into a common step-by-step sequence. Several blocks are optional as not all beams will use all features. Additionally, it is important to point out that the treatment room & default spot placement parameters are set outside of the individual beam creation tasks as these apply to all beams (however, spot placement parameters can be overridden within each beam if desired). An example of constructing a lateral beam, with the isocenter at the centroid of the PTV is given below to illustrate the features available when defining a beam.

Treatment Room & Mode Type (SOBP or PBS)

1. Within the *Plan Overview* select the *Beams* block
2. From this interface you can select the treatment room, including the treatment mode
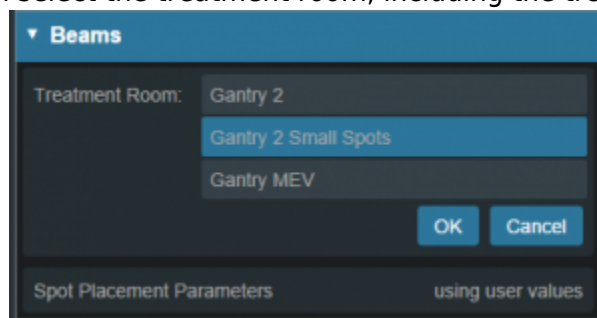
3. If the treatment mode is PBS you can then select and define the plan level PBS *Spot Placement Parameters*. Edit these parameters to define the spot placement grid for each beam in the plan,

noting that individual beams can override these values during beam creation if you so desire

Beam Creation

- The next step is to create the beam by clicking the:
    - *Create New PBS Beam* button for use in PBS treatment rooms
    - *Create New SOBP Beam* button for use in SOBP treatment rooms
- Now we will proceed step-by-step through the various "blocks" to create a complete beam as shown below:

General Settings

The **General** block is used to set general beam details including:

- Color, Beam Label (or select *automatically generate label*) and Description

PBS specific

For PBS beams the following additional options will be available:

- **Geometric Target** is used for approach and device creation. You may choose an existing target or create a new structure. For this example we chose the PTV_7920 as the geometric target. The geometric target will be used to define the extents of the aperture (if used) and will be linked to the isocenter position (if target centroid is selected in the approach block).
- **Spot Target** is used to define the extent of the PBS spot placements for the beam. The spot target can either match the geometric target, or the user can choose to use the target for the fraction group in which the beam is used (useful for allowing the same geometric beam to be used in multiple fraction groups by simply recomputing the spot positions based on the fraction group target).
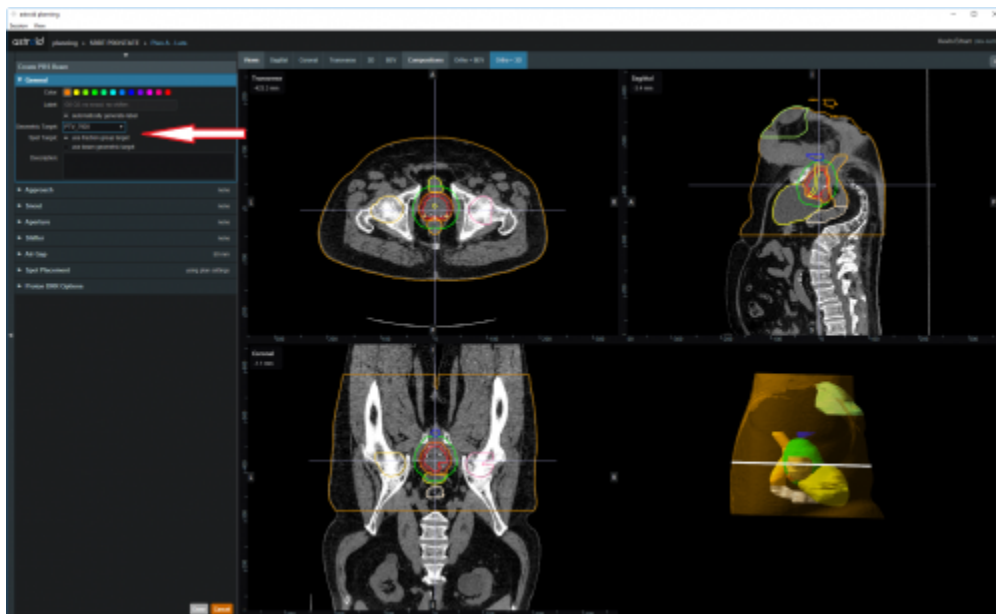
SOBP specific

For SOBP beams the following additional options will be available:

- **Target** is used for approach and device creation, and it can be either a structure or an existing beam.
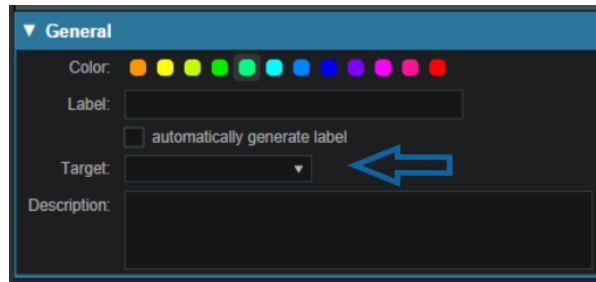
- If the target selected is an existing beam, the new beam becomes a **Patch beam**. Thus, the targeted beam becomes a parent thru-beam of the current patch beam (child).
    - The patch dose field box is then enabled, allowing users to enter a dose value amount. The parent beam's target will reduced such that any portion receiving a dose from the parent beam that is greater than this amount will be ignored when designing the patch beam range compensator. In other words, the target of the patch beam becomes the target of the parent beam, minus the volume enclosed by the isodose surface (compute only for parent beam) at the defined patch dose value. This patch beam target can be viewed in the Display UI and toggled on and off in the right hand side beam controls.
    - Patch beams can also be "chained" beyond a single parent-child pair by creating a beam and selecting the desired patch beam as the target.
    - Also note, that once a beam is designated as a patch and added to a fraction group, it cannot be changed back to a standard non-patch beam. In such cases, you must either remove the beams from the Fraction Group first, or a new SOBP beam must be created.

Beam Approach

In the Approach block specify the desired isocenter from the dropdown. You may choose to use the centroid of the Geometric Target (as shown below) or you can select or create a new point to define the location for the isocenter. The gantry angle and couch angles are also entered here as well. Editing these values can be done by typing directly in the provided fields or by using the sliders. The patient in this example is feet first so we will use 90 for the Gantry angle and 0 for the Couch Angle to create a left lateral beam.
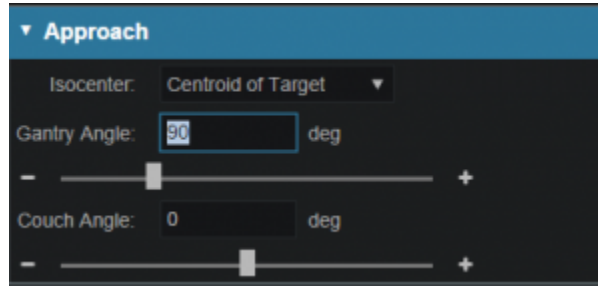
Snout

In the snout block a list of snouts associated with the specified treatment room will be available to choose from. Selecting a snout can change what beamline devices are available based on the facility model in the site info.

Apertures

An option to add an aperture can be found within the *Aperture* block. An *Aperture* was not chosen in the PBS beam example. Although selecting an aperture is optional for PBS beam plans, selecting an aperture is **required for SOBP beam** plans.

- Refer to Creating a New Aperture for detailed instruction

Shifters (PBS)

The Range Shifter block is only available for PBS treatment modes.

- If desired, select the range *Shifter* to use based on the ones available for the selected snout. If no *Shifter* is needed as in the example given, the user may go to the next step

Air Gap

Once the beam line devices are defined, we can move to specify the *Air Gap* distance. The valid air gap range will be listed based on the selected snout. The user may choose any value in this range. 30mm was chosen in the below example.

Beam Spot Placements (PBS)

The Spot Placement block is only available for PBS treatment modes.

- With the beam positioned and any beamline devices put in place, the user is ready view the PBS Spots and adjust the *Spot Placement* values if needed. The *Spot Placement* box, if chosen, will allow the user to set new parameters, overriding the spot placement parameters for this one beam

if desired. The example below illustrates the message shown when using the spot placement values from the plan level.

Proton DRRs

Proton DRRs do not impact the beam and are used purely for visualization purposes so that you can set the DRR Options to levels that generate appropriate anatomy visualizations. An example DRR is shown below. Note that Astroid allows you to define 2 distinct DRRs and then blend them together using a simple weight factor to create a single DRR image on the screen. This gives users the freedom to create high contrast, high quality DRR visualizations. A single image was used in the example below as the second set of DRR options has the weight set to 0.
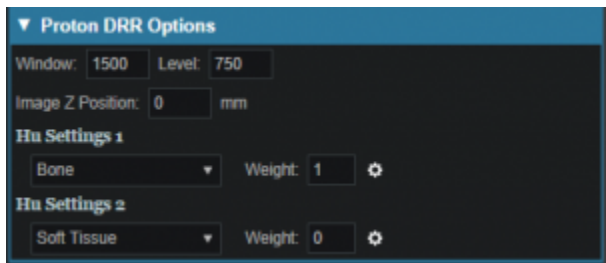

2016/08/17 12:58

Creating an Aperture

An aperture can be added for any snout that has slabs defined for use in the site specific machine model. The site model also includes a definition for the aperture milling tool and Astroid enforces the "millability" of all apertures so that dose is only computed using a device that exactly matches what will be manufactured. The user has the ability to utilize apertures for all types of proton delivery including: PBS, DS, and US. The major steps involved in creating an aperture are common to all delivery modes, so the PBS beam example below can be referenced for all cases.

Adding an Aperture

PBS

- From within the PBS Beam Task you may add an aperture to a beam by clicking the "Add One" button from within the *Aperture Task Block*.
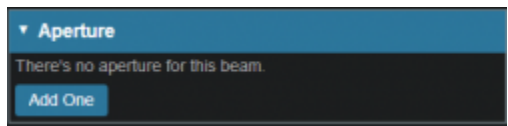

SOBP

- From within the SOBP Beam Task, an initial aperture is automatically created (note: the "Create

New Hardware" option is selected from within the *Aperture Task Block*) based on your site configuration default margins and the selected beam target. Changes to the default aperture can be made according to the instructions and descriptions below if needed. Alternatively, you can re-use an existing aperture by clicking the "Re-Use Existing Hardware" button. Selecting the "Re-Use Existing Hardware" option ensures that the current beam will use the exact same device used in an another beam within the plan.

Target

- Your target structure is automatically selected from your beam setup information. So you need to only specify the number of millimeters you want to expand your aperture around the target structure using the "Margin" option to generate your initial aperture shape. For this example we will give a margin of 10mm around the PTV7920.
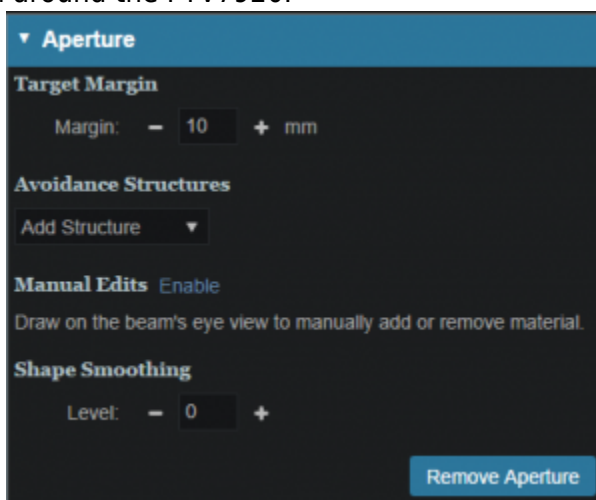
  - Your aperture should now appear in the BEV display window.
  - As seen in the example, the aperture is created so that it there is a 10mm margin from the PTV7920 to the edge of the aperture.
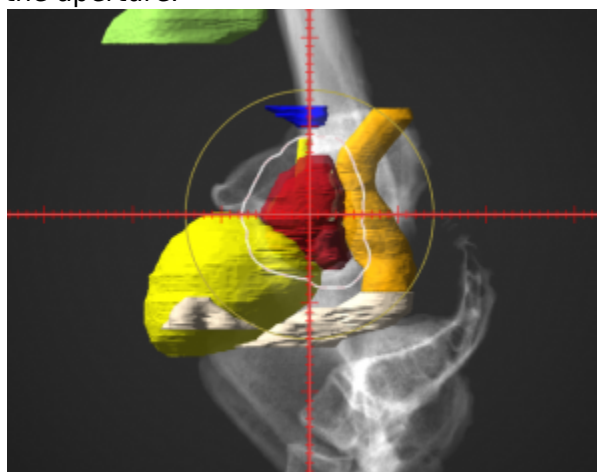
Avoidance Structures

- In many cases you may have nearby critical structures that must be avoided. You can add an "Avoidance Structure" to your aperture design by clicking on the "Add Structure" dropdown and selecting a structure.
- Once added you can now specify a margin (mm) around this structure if desired (note negative margins will reduce the size of the blocked area, exposing part of the structure to the open field).
    - You may also choose to occlude the structure by the target or not using the "Occlude by Target" option. For the following examples we will use the Urethra as it shows a dramatic example of differences of using or not using the "Occulde by Target" option. A 2mm margin was applied to the Urethra for the following examples.
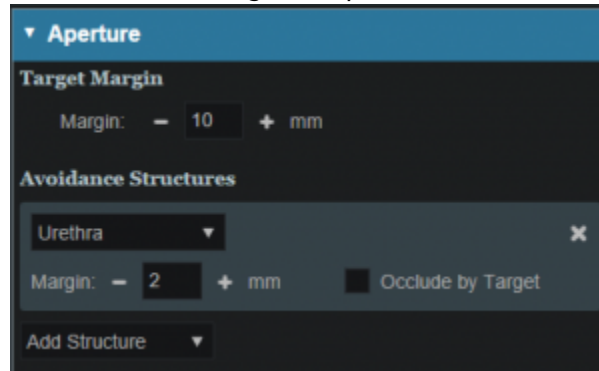
        - By checking the "Occlude by Target" box you are choosing to give the target priority over the structure in the view you are looking at in the DRR. In other words the visible target (target in front of this structure) will not be blocked by the aperture. Note that just the inferior edge of the Urethra is blocked by the aperture. The part of the Urethra that is behind the PTV7920 is not blocked.
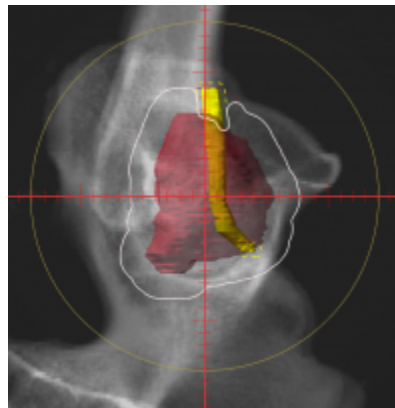
        - If you leave the "Occlude by Target" unchecked, you are choosing to give the structure priority over the target. This means you will block the entire structure regardless of its position relative to the target. In this example the aperture blocks out all of the Urethra.
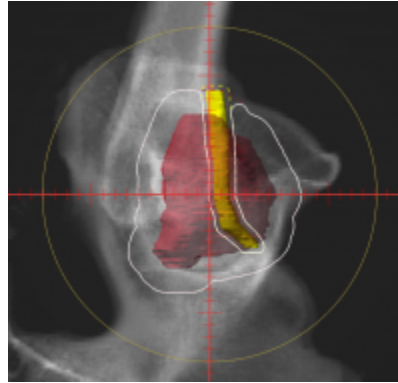
- You may add as many Avoidance Structures as needed to design your aperture shape.

Shape Smoothing

- The "Shape Smoothing" section allows you to smooth the aperture if needed.
- The smoothing level value can be set from 0-20, with zero applying no smoothing and higher numbers increasing the smoothness of the aperture. See dosimetry explanation on aperture smoothing for more details regarding the smoothing algorithm and process.

Manual Edits

- Manual edits allow you to draw on the BEV in order to manually edit the aperture shape. To begin editing simply click the *Enable* link.
- First, set the radius of the editing tool to the desired size (you can directly type a size or use the -/+ on either side to increment the size)
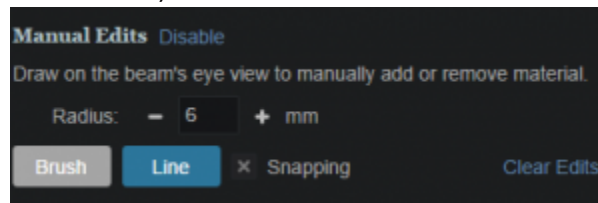
- You are now free to draw manual override regions directly on the BEV. You draw by simply clicking and dragging the mouse at the desired positions.
  - You have the option to use a freehand brush tool or a straight line drawing tool for performing manual edits.
    - While using the straight line tool, the Snapping option allows snapping for horizontal, vertical, and 45 degree angles.
  - The editing tool automatically switches between adding or subtracting material based on the position of the tool when the mouse is first clicked (i.e. when starting each new draw operation).
    - When outside the aperture, you edit the aperture by pushing in/subtracting and your edit regions are drawn in a blue color. The hashed red line denotes the original placement of the aperture.
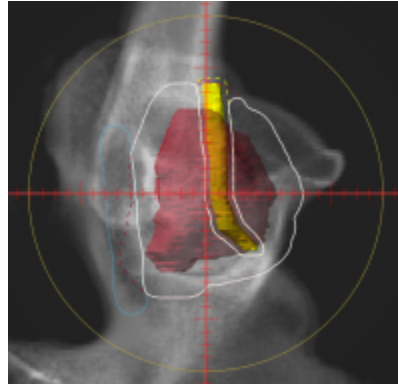
- When inside the aperture, you edit the aperture by pushing out/adding and your edit regions are drawn as the color of your target.
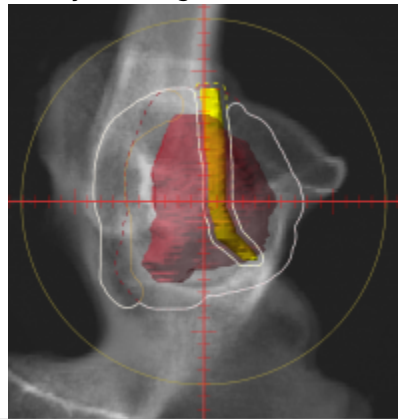
- The manual edits contain an "undo" feature, so that the user can successively remove the last manual edit step by pressing Ctrl+Z. Please note that the undo functionality only tracks edits performed in the active session, so as soon as you leave this block or disable manual edits, you will be unable to use the undo functionality on those changes when returning to this task.

- Once done with manually editing, click the "Disable Editing" button to end the process.
- Note that your edits and the resulting aperture shape will still show on the BEV and your edits will remain as-drawn even when changing other options.

Removing Edits

- If you need to remove the manual edits for any reason, you may do so by pressing the "Clear Edits" button. Pressing this button will remove <u>ALL</u> manual edits for this aperture.
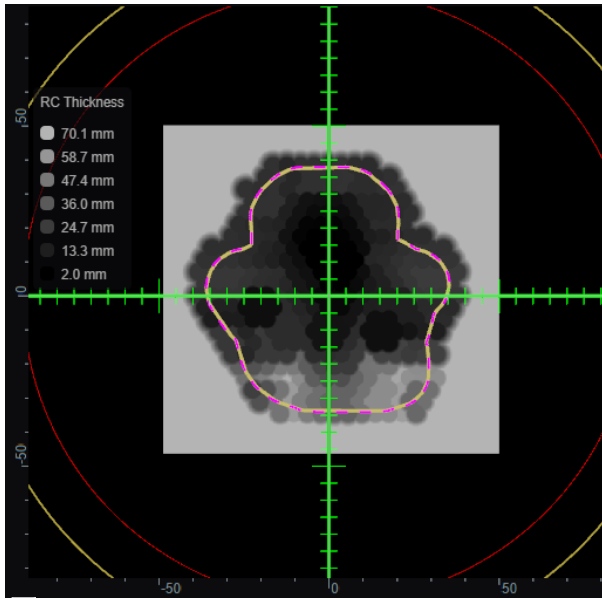
Removing an Aperture

- If you wish to remove the aperture from this beam, simply press the "Remove Aperture" button at the bottom of the Aperture Task Block to completely remove it.

2016/08/17 12:58

Creating a Range Compensator

> **Note:** Range compensators can only be added to SOBP beams.

Range Compensator BEV Thickness Image

A range compensator is automatically added for any snout that has range compensator information defined for use in the site specific machine model. The site model also includes the maximum and minimum possible thickness values, the material, and the extents (outer dimensions) of the range compensators for each snout.

Re-using Existing Hardware

- From within the SOBP Beam Task, you may either create a new range compensator or re-use a range compensator that already exists in the plan. This option ensures that the current beam will use the exact same device defined by another beam within the plan.
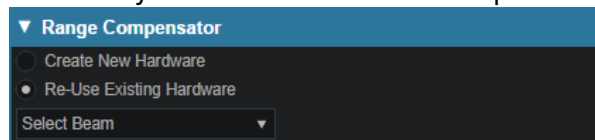
Geometric or Dose Based

- Astroid has two algorithms to design proton range compensators, a standard geometric approach and a dose based option. Each is explained below.

- Geometric:
    - Ray tracing is used to determine the water equivalent depth (WED) at the distal surface of the target volume throughout the entire treatment field
    - Using this data, the appropriate thickness of range compensator material is added to each rayline such that protons will stop at the distal target surface (thickness = r90 - WED)
   - This is the standard design approach for range compensators in nearly all other planning systems
- Dose Based:
    - This approach begins with a standard geometric design
    - Then the actual dose delivered from this field using the current compensator is computed
    - Ray tracing is then used to compute the distance between the actual (computed) 90% isodose surface and the distal target surface throughout the entire field
    - Material is then added or subtracted from the range compensator for each rayline, based on the difference in depth between these two surfaces
    - The process repeats from step 2 for a predefined number of iterations (defined in the site info, and should typically be between 3-10)
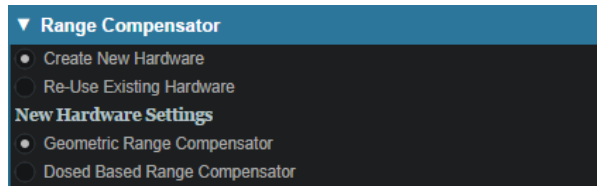
Range Compensator Parameters

- The range compensator calculation uses a distal range margin that is the addition of the user-defined "Range Margin Distance" and the "Range Margin Percentage" of the beam range. The "Smear Radius" is a distance over which to reduce heights of nearby drill points to avoid narrow valleys in the compensator surface and improve treatment robustness. All drill points are dropped to the lowest height neighbor within this radius. The "Target Distal Dose" is the dose value that the range compensator calculation will try to achieve on the distal edge of the target (most typically 90%).
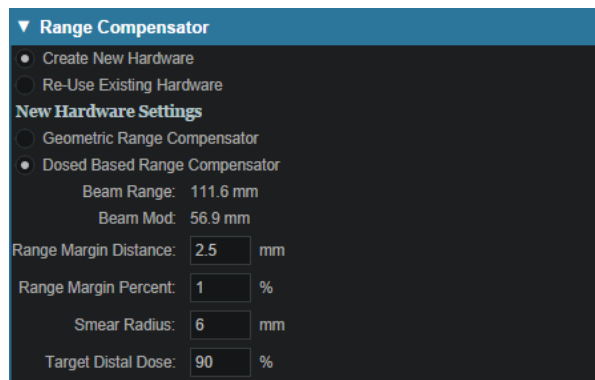
2019/07/30 13:54
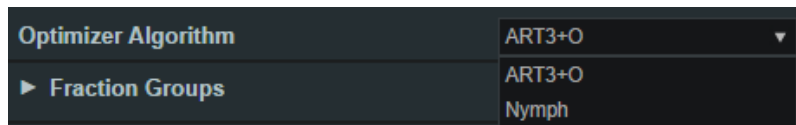
Astroid Optimization (PBS)

With intensity modulated PBS treatment plans the variety of possible dose distributions is quite large. Typically if a physician does not like a plan they will request it to be re-run. This requires the planner to input new constraints and objectives and a new plan to be run from the beginning of the optimization process. This is a time consuming process. Astroid eliminates this cycle using a Multi-Criteria Optimization (MCO) approach that allows planners and physicians to visualize the trade-offs of target volume coverage vs reduced dose to the OAR's in real time. MCO treatment planning is based on a set of Pareto optimized plans, where a plan is considered Pareto optimal if it satisfies all the constraints and none of the objectives can be improved without worsening at least one of the other objectives. So instead of creating just one plan, Astroid creates a set of optimal plans that satisfies the treatment plan constraints and puts an interactive exploration of the objectives at the planners and physicians fingertips via a unique, highly intuitive, solution navigation slider bar system.

Constraints play an important role in the optimization process, as they bound the solution space and ensure your navigation process is focused only on plans that meet your non-negotiable, highest priority dosimetric needs. It should be noted that if the *constraints* are too tight, there may be no feasible plans. However, if the *constraints* are too loose, too many solutions will exist and the navigation will be too broad to provide adequate resolution over the truly clinically useful plans. Therefore care should be taken to ensure appropriate constraints are set, which is facilitated using the Astroid *Feasibility* check feature. So while constraints supply hard limits, *objectives* are the negotiable goals, they do not have a hard level that must be obtained, but "pushing" them harder does result in benefit to the patient. The number and type of *objectives* chosen should be such that all the relevant trade-offs can be demonstrated and explored.

Optimizer Algorithm Selection

The user is able to select the MCO optimization algorithm from a list defined in the site configuration settings. The default option is the first algorithm in this site level list of pluggable_functions designated with the mco_optimizer key.

As of Planning 2.3.2 the available optimizers are Art3+O and Nymph. Both optimizers use the same constraints and objectives. However Nymph does not use a separate feasibility stage and has it built in to the optimization step.
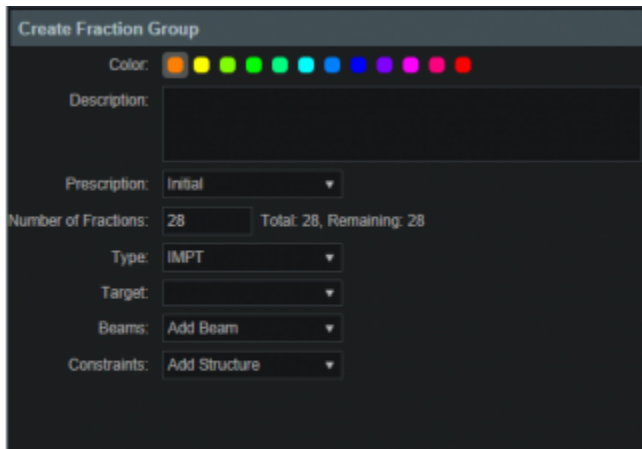

PBS Fraction Groups

Defining *Fraction Groups* is the first step in the PBS Optimization process within Astroid. Most commonly, a fraction group is simply an arrangement of beams that will be used in a typical daily treatment fraction. The Fraction Group contains some basic group information, as well as Fraction Group level constraints
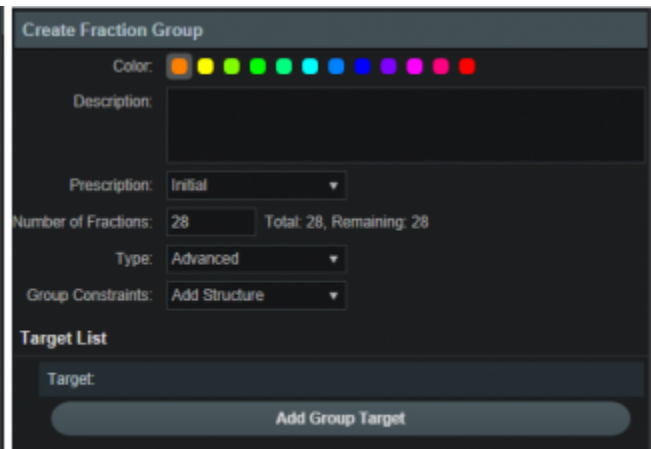
and collections of *Beam Sets* and *Constraints* for each target of the fraction group. The *Beam Set* and various *Constraint* levels are key concepts within Astroid that allow for high levels of control over the Astroid PBS Optimization engine. Further details of these critical items are provided below and additionally, examples of some common cases and how fraction groups, targets, and beam sets can be constructed to meet the clinical needs of various clinical cases can be found in the Prostate Plan Walkthrough.

General Fraction Group Data

- **Color**: Display color of the *Fraction Group*
- **Description**: Optional, user specified text describing the *Fraction Group*
- **Prescription**: Prescription that the *Fraction Group* implements; note that only targets containing dose statements from this Prescription will be available when selecting the Target for the Fraction Group
- **Number of Fractions**: The total number of fractions to be delivered for this *Fraction Group*; this is very important as it will determine the appropriate Monitor Units for the individual beams
- **Type**: The delivery approach that will be used for the beams in the Fraction Group. Options for this include SFO, IMPT, and Advanced. If either SFO or IMPT are selected the Fraction Group user interface will remain in "Simple Mode", whereas selecting Advanced as the type will switch the interface to the "Advanced Mode"

Simple Fraction Group User Interface
(for SFO and IMPT options)

Advanced Fraction Group User Interface

Simple Type Fraction Groups

SFO

Single Field Optimized treatments are created using this type option. Simply select *SFO* from the *Type* drop down and then add any number of beams and constraints. Each constraint will be equally divided among each beam during optimization. For example, if three beams are included in the Fraction Group and a PTV min constraint of 60 Gy(RBE) is added, then each beam will be individually set to have a constraint of 20 Gy(RBE) (60/3) when running the optimization.

> **Note:** A fraction group with only one beamset and a single beam will always be considered to be an SFO fraction group.

IMPT

Intensity Modulated Proton Therapy treatments are created using this type option. Simply select *IMPT* from the *Type* drop down and then add any number of beams and constraints. These constraints will be applied to the collective (total) dose from all beams in the Fraction Group. Using the same example as the SFO section, if three beams are included and a PTV min constraint of 60 Gy(RBE) is added, then the total dose from the three beams must be above 60 at all points within the PTV, however, no restrictions are placed per beam, so that each beam is free to give any portion of the 60 Gy(RBE) dose. This allows for maximum flexibility in sculpting dose to the target, but generally at the expense of increased sensitivity to motion and patient positioning uncertainty.
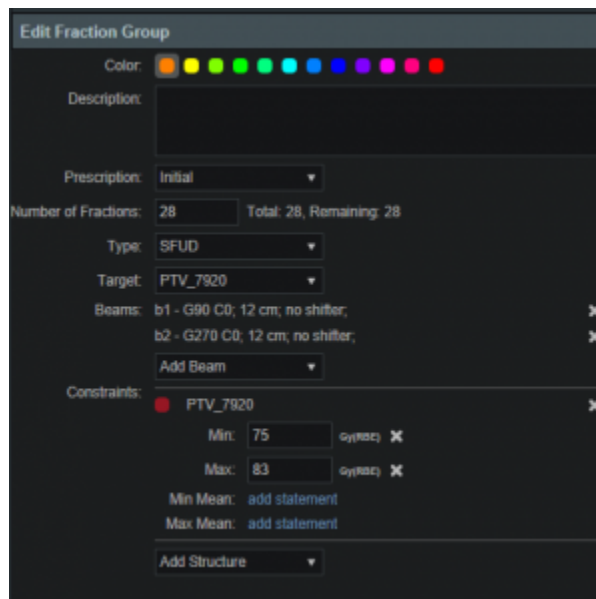
Advanced Type Fraction Groups

Advanced type fraction groups are needed only in rare occasions when beams must be mixed such that a standard IMPT or SFO approach simply doesn't provide the necessary control over the constraints. Since the advanced more UI is significantly more complex, the following section is dedicated to providing a more detailed understanding of the available options. It should be noted that Advanced mode allows for multiple targets and for constraints to be specified at the Fraction Group level and the Beam Set level and it is important to learn these differences in order to make proper use of the advanced options.

Fraction Group Targets

Simply speaking, a Fraction Group Target is just a collection of *Beam Sets* and *Constraints* that together will provide a specified dose to a particular target. In clinical practice, most standard single lesion treatments will use only one Fraction Group Target. More complex prescriptions, such as Simultaneous Integrated Boosts (SIB), generally contain two Fraction Group Targets, one for the primary target and a second for the boost target. Within the Fraction Group Target, a target structure is specified along with one or more *Beam Sets* and any beam set level constraints necessary to meet the clinical goals for this target.

- **Target**: The target structure for the beam sets that will be defined below. The available selections will only contain targets with prescriptions specified for the phase selected in the main *Fraction Group* and that also exist in the treatment plan (note this excludes Directive level structures with prescription information, but no physical contour data).
- **Beam Sets**: A list of Beam Sets that will be used to achieve the specified constraint doses (see below for a more detailed definition of a *Beam Set*).
- **Constraints**: These Beam Set Level *Constraints* are split evenly and applied individually to each *Beam Set*
    - In other words, the Constraint dose is divided by the number of Beam Sets for the Target, so that both SFO and IMPT can be achieved

Beam Sets

The *Beam Set* is the lowest level unit for the Astroid PBS Optimizer and proper arrangement of the beams within a beam set allows for both Single Field Optimized (SFO) and Intensity Modulated Proton Therapy (IMPT) fields to be included within the same fraction. A careful review of the Beam Set Level (BSL) Constraints described above, should reveal how to properly arrange beams within Beam Sets to achieve a desired type of treatment. Since BSL Constraints are equally split and are then applied individually to each Beam Set, SFUD beams can easily be achieved by placing each beam in its own Beam Set. Conversely, IMPT beams are created when multiple beams are included within a single Beam Set. Further details of these two cases are presented below, as this will provide the information necessary to allow users to construct complex constraint relationships, which is the purpose of the Advance type UI.

SFO Beams

Single Field Optimized treatment beams are produced by including each beam in a separate Beam Set. This is best understood by example. Suppose a target is intended to receive 20 Gy (2 Gy per day for 10 fractions) from a two beam Fraction Group using a SFO approach. This is achieved by specifying a min dose of 18 Gy and a max dose of 22 Gy using Beam Set Level Constraints. Now two beam sets are created, each containing a single beam, as shown below. Since the BSL constraints are split between the beam sets, this actually tells the optimizer that each beam must provide a min dose of 9 Gy and a max dose of 11 Gy (1/2 of the BSG constraint doses). Therefore, each individual beam will be providing coverage to the entire target as is expected for a SFO approach.
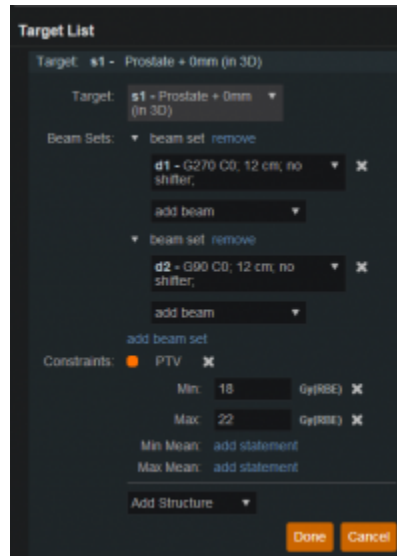
IMPT Beams

Intensity Modulated Proton Therapy treatment beams are produced by including all desired beams in a single Beam Set. This is again best understood by example. Suppose a target is intended to receive 20 Gy (2 Gy per day for 10 fractions) from a two beam Fraction Group using an IMPT approach. This is achieved by specifying a min dose of 18 Gy and a max dose of 22 Gy using Beam Set Level Constraints. Now one Beam Set is created, containing both beams, as shown below. Since there is only Beam Set, the BSL constraints will be applied to the combined dose from the two beams. Therefore, there are no guarantees regarding the uniformity of dose from either beam and instead there is simply the guarantee that the combined dose from the two beams meets the given constraints, thereby producing an IMPT treatment approach.
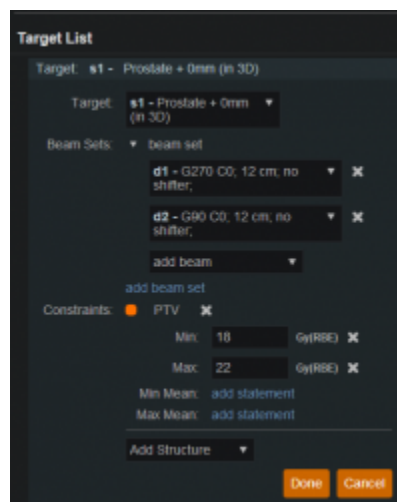

By understanding the notion that Beam Set Level Constraints are equally split among the Beam Sets, it can also be seen how SFUD and IMPT may be mixed within a Target and even the most complex of treatment scenarios can be handled seamlessly in Astroid.

Working with Fraction Groups

1. Select the Create New Fraction Group button
2. In the newly opened block the planner will:
   - Choose the color the fraction will be denoted in
   - Type in any descriptor that may be needed
   - Select the phase that the fraction group is implementing
   - Enter the total number of fractions to be treated
   - Enter the group constraints if desired
     - Group constraints apply to the total dose from the whole fraction group
     - Constraints for multiple structures may be entered at this stage
3. Click *Add Target*
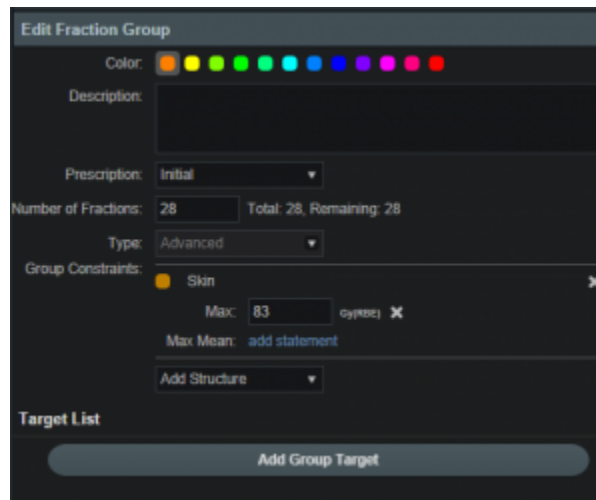
   - Select the target structure
   - Create any Beam Sets that are desired
     - There may be multiple Beam Sets associated to a target to construct SFUD or IMPT beam groupings (see above for further details)
   - Enter any desired Beam Set Level constraints
     - The constraints chosen at this point will be evenly divided and applied separately to each Beam Set (see above for further details)
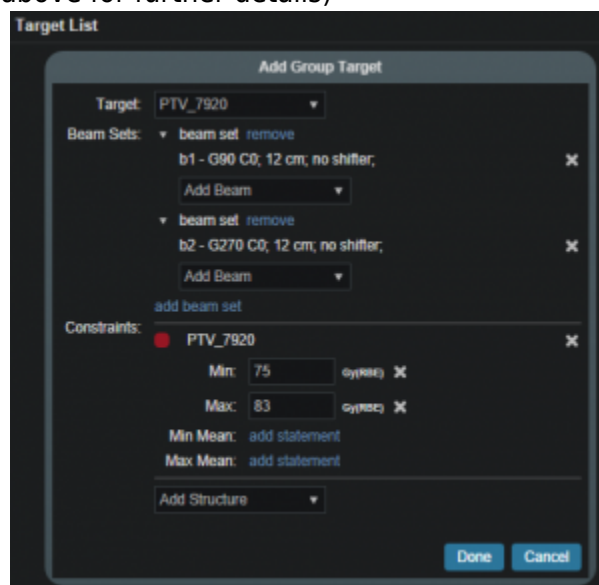
- The user may also have multiple Targets, with each associated to a distinct target within the selected *Fraction Group* Phase

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Optimization Constraints

About Constraints

Constraints can be specified at various levels (*Plan, Fraction Group, Target/Beam Set*) with Astroid and they will affect different groups of beams depending on their level. *Constraints* at the *Plan* level are applied to the total dose resulting from all beams. *Constraints* at the *Fraction Group* level are applied to the total dose resulting from only the beams in the current Fraction Group. *Constraints* at the *Target/Beam Set* level are split evenly and applied individually to each Beam Set. In other words, the *Constraint* dose is divided by the number of *Beam Sets* in the *Target*, and this dose is then applied as a constraint to each Beam Set, so that either SFUD and IMPT can be achieved (see Fraction Groups). The section below will provide a walk through of the different levels and how constraints are applied at each one.

It should be noted that all constraints are considered "hard limits"- values that <u>must be</u> achieved. *Constraints* drive the feasibility calculation- whether the plan is achievable and should be used to ensure certain minimal clinical parameters are met.

The following constraint types are available. Note certain constraints are available only for *Target* type structures.

- **Min**: The minimum dose the structure must receive
- **Max**: The maximum dose the structure may receive
- **Min Mean**: The minimum mean dose a structure must receive
  - This will drive the dose up across the structure
- **Max Mean**: The maximum mean dose a structure may receive
  - This will limit the mean dose across the structure
- **Overdose**: The maximum sum of the overdose that a structure may receive (*not available for ART3+O optimizer*)
  - This will limit the total volume-weighted overdose (dose above a given threshold) that a structure receives, driving down hot spots
- **Underdose**: The maximum sum of the underdose that a structure may receive (*not available for ART3+O optimizer*)
  - This will limit the total volume weighted underdose (dose below a given threshold) that a structures, driving up cold spots
- **Hot Spot Vol**: The maximum mean dose to the hottest portion of a structure (*not available for ART3+O optimizer*)
  - This will keep the mean dose to the hottest portion of a structure below the given limit; portion is set as a % vol and the limit is the max mean dose allowed to that portion of the structure
- **Cold Spot Vol**: The minimum mean dose to the coldest portion of a structure (*not available for ART3+O optimizer*)

○ This will keep the mean dose to the coldest portion of a structure above the given limit; portion is set as a % vol and the limit is the min mean allowed to that portion of the structure

The user can choose to apply one or multiple of these constraints to any number of structures.

Working with Constraints

Working with Fraction Group and Target/Beam Set Constraints

Constraints at the *Fraction Group* level are applied to the total dose resulting from only those beams in the current *Fraction Group*. *Constraints* at the *Target / Beam Set* level are equally split among the Beam Sets within the Target and are applied to the total dose resulting from the beams in each of the Beam Sets. The following steps are a brief walkthrough for creating a max constraint of 79.2 Gy(RBE) to the PTV for the whole Fraction Group, and then creating two SFO beams that each provide a minimum dose of 39.6 Gy(RBE). Note that this configuration with the max constraint at the Fraction Group Level is different than if we had put both the min and max at the Target / Beam Set level. In the case shown, it is only the total dose from the two beams that is constrained to be below 73 Gy(RBE). Had both constraints been placed at the Target Level, then each beam would instead be constrained to a max of 36.5 Gy(RBE).

1. Select the *Fraction Group* if it has been created or create a new one by clicking *Create New Fraction Group*
2. Choose the prescription, number of fractions to be treated with this Fraction Group
3. Choose the type of treatment (SFO, IMPT, Advanced) and target
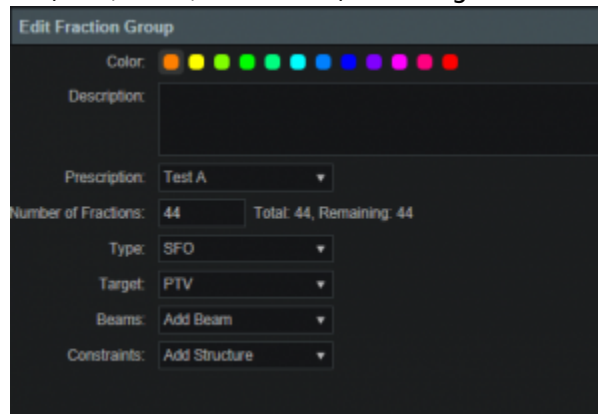

4. Choose the *Beams* to be treated
5. Choose the *Target* to be treated
    1. Assign the dose constraints to the *Target*
    2. The assigned constraint doses at this level will be divided evenly among the *Beams* to the *Target*, which allows for quick creation of SFO treatments

Working with Plan Constraints

Constraints at the *Plan* level are applied to the total dose across all beams.

1. Open the *Constraints* sub block contained in the *Constraints/Feasibility* block and choose the *Edit* button.
2. Choose from the drop down the structure or structures to which constraints should be added
3. Define what constraint(s) should be applied to each structure by choosing the constraint and entering the dose
4. Follow this and enter the constraints for all applicable structures.
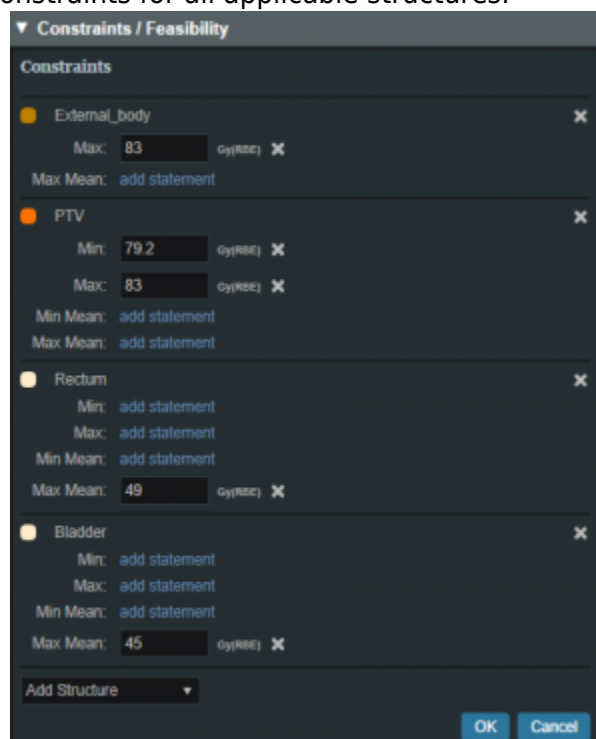
5. When finished click the *OK* button.
6. Once all the Constraints have been set the user can either start the Feasibility by choosing *Calculate* or move on to defining the Objectives

Feasibility and Constraints

After the *Constraints* have been entered, the user may start the *Feasibility* calculation by clicking *calculate* in the *Feasibility* block. The *Feasibility* calculation is based solely on the *constraints* and, it should be used to ensure that it is possible to meet the specified constraints. The *Feasibility* calculation may be an iterative processes in order to get appropriate constraints established for a particular plan. In other words, the user may need to enter one or more constraints, check the feasibility, then progressively tighten the constraints and re-check the feasibility until the plan is no longer feasible, then back-off to the last feasible values. It is recommended practice to start by obtaining a feasible plan utilizing only target *Constraints* then add OAR *Constraints* as desired. Remember, using a narrow range of constraints can improve the optimizer performance and improve the resolution of the solution navigation.

The user also needs to be aware of the impact of *Constraints* being set at the *Fraction Group* level versus the *Plan* level. For example, it is possible to have a *Constraint* set in the *Plan* level so that the whole dose to an OAR is given on one day and none on the other day. This could happen when there are two *Fraction Groups* and the OAR dose is not split between the two by using Fraction Group level constraints.

Optimization Objectives

Objectives communicate to the optimizer the goals that are important to strive for in your plan. *Objectives* are set at the *Plan* level under *Plan Constraints/Objectives* and they apply to the total, combined dose from all beams. *Objectives* are not given any relative importance at this point (i.e. their order within the list is not meaningful). The *Objectives* drive the solution of the Multi Criteria Optimization (MCO) and for each *Objective*, a corresponding *Navigation Slider* will be presented to allow for exploration of trade-offs in the case of competing objectives (for more information about the MCO process and how objective importance/weighting is handled in Astroid refer to this article).

The following objective selections are available in Astroid:

- **min_max**: Minimize the maximum dose within a structure (drive dose down)
- **max_min**: Maximize the minimum dose within a structure (drive dose up)
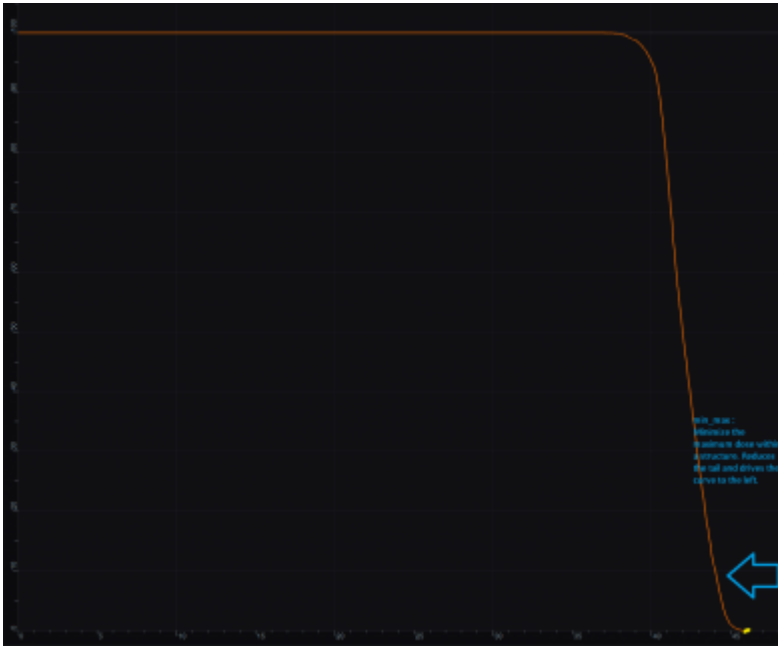
min_max: Minimize the Max Dose
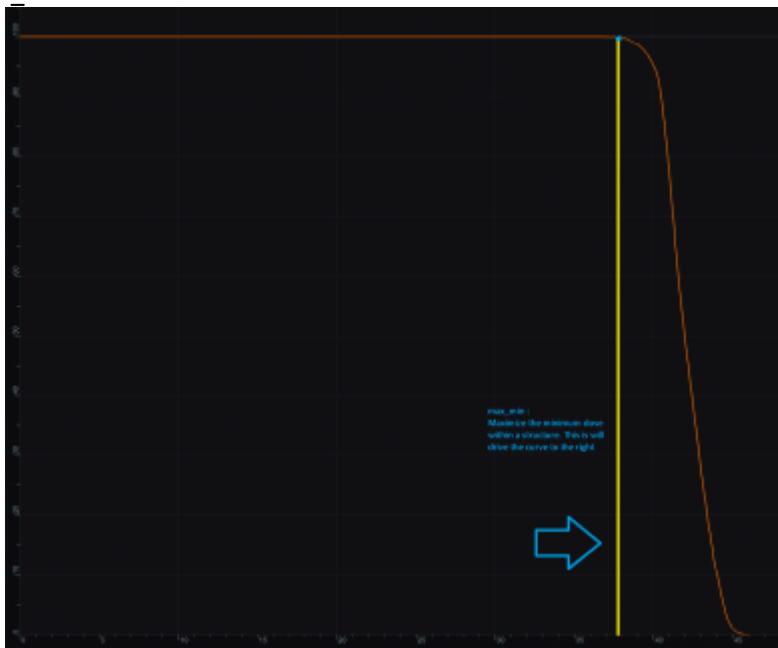
max_min: Maximize the Min Dose

- **min_mean**: Minimize the mean dose within a structure (drive dose down)
- **max_mean**: Maximize the mean dose across the structure (drive dose up)
- **min_overdose**: Minimize the high dose within a structure
    - Dose will be driven down only until the specified limit is reached (this is often more relevant that min_max, since it may not be beneficial to continue minimizing beyond a certain dose level)
- **min_underdose**: Minimize the low dose within a structure
    - Dose will be driven up only until the specified limit is reached (this is often more relevant that max_min, since it may not be beneficial to continue maximizing beyond a certain dose level)
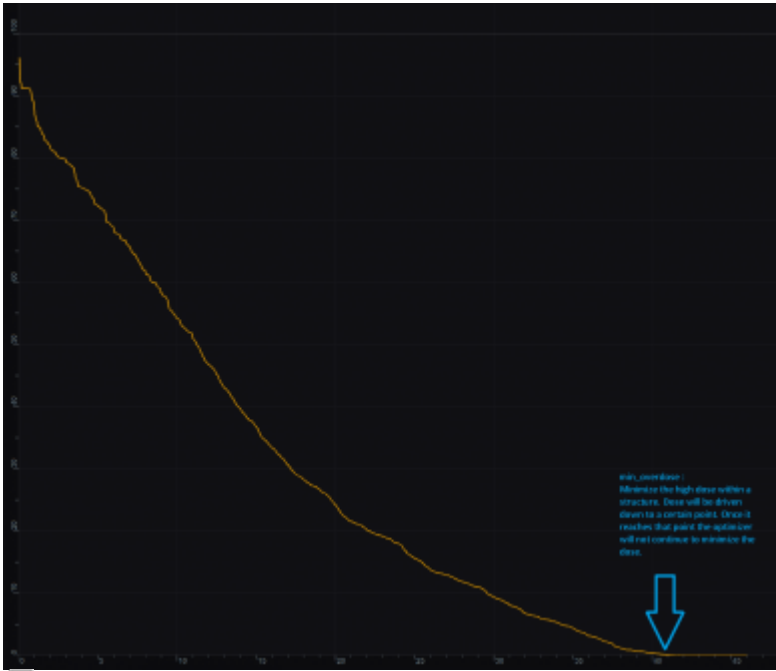
min_overdose: Minimize the high dose
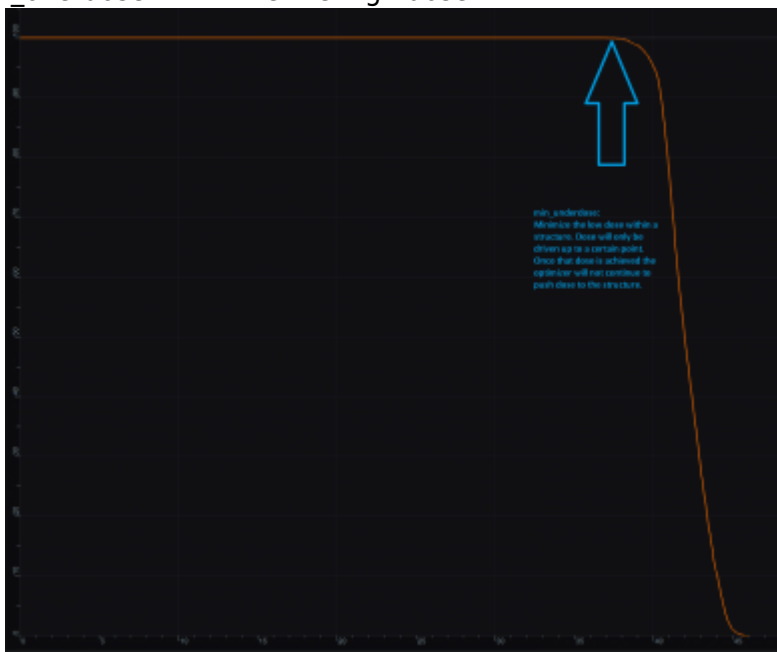
min_underdose: Minimize the low dose

- **min_hot_spot**: Minimize the mean dose to the hottest portion of a structure (*not available for ART3+O optimizer*)
    - The mean dose to the hottest portion of a structure will be driven down (i.e. the tail dose on the DVH); portion is set as a % vol of the structure
- **min_cold_spot**: Maximize the mean dose to the coldest portion of a structure (*not available for ART3+O optimizer*)
    - The mean dose to the coldest portion of a structure will be driven up (i.e. the shoulder dose on the DVH); portion is set as a % vol of the structure

Working with Objectives

1. Open the *Objectives/Optimizer* sub-block contained in the *Optimization* block
2. Choose a structure to which you wish to apply objectives
3. Check the boxes to activate the desired objectives for the structure and then set the dose level if applicable
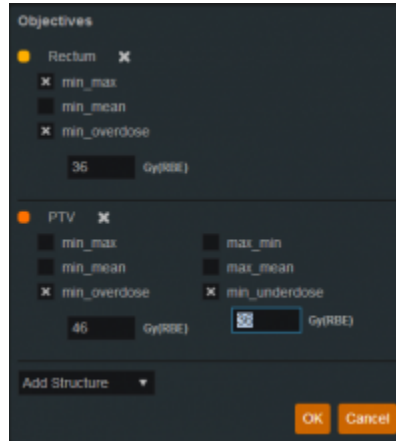
Once all the *Objectives* have been set, the user is ready to run the MCO solver, which is performed in the *Objectives/Optimizer* block.

Running the Optimizer

The *Objectives*, as stated before are the negotiable goals where there may be no hard limit, but there is benefit to improving them. Astroid allows *Objectives* on both Targets and OAR's. *Objectives* can be placed on structures to either increase or decrease dose. The *Objectives* are the sole driving force guiding the MCO and it is important to recall from the discussion above that Astroid will only navigate to plans that are "optimal" in at least one objective (meaning again that this objective cannot be improved without another objective getting worse). Unlike *Constraints*, *Objectives* should be added all at once and there is no need to place them in any particular order (order is irrelevant). Additional information about *Objectives* can be found here. Since the MCO is finding a large set of optimal solutions the optimization can be a lengthy process. The following factors have the largest impact on the optimization run time:

- The number of points in the calculation grid
- The total number of spots from all beams

The number of calculation points and number of spots will have a direct impact on the calculation times meaning that increases in these values will also increase the MCO calculation time. The number of objectives does not always increase the overall run time of the calculation however, thanks to the parallelization that be achieved using the Astroid cloud services, though the number of objectives does impact the usable capacity of calculations that can run on the Astroid cloud. The speed and number of running calculations will depend on the availability and load on the Astroid cloud calculation servers. Each objective of the MCO calculation is computed on a separate thread of a calculation server, therefore understanding the usage of these servers can help users make decisions regarding resource usage for a

given set of objectives. The Astroid MCO calculations are designed to use servers in CPU increments of 16 and the MCO calculations are posted to calculation servers as follows:

- 1-16 objectives: a single 16 core calculation will be issued, with an objective being run on each core
- 16-32 objectives: a single 32 core calculation will be issued, with an objective being run on each core
- >32 objectives: a single 32 core calculation will be issued, and the server will be responsible for balancing the load to achieve full CPU utilization

Understanding this pattern is important, as it can be seen that using less than 16 objectives generally will have minimal impact on MCO run-time and no impact on resource usage. Using between 17-32 objectives will use additional resources, but generally not impact run-time, but using >32 objectives will increase the MCO run-time without using additional resources.

Once all the desired *Objectives* are entered the MCO calculation is started just by clicking the *calculate* option in the *Navigation* block. It should be noted that the *Feasibility* will be re-checked if any of the *Constraints* have changed since the feasibility was last run. The MCO calculations will run in the cloud and the user can simply leave the Astroid application running and move on to other things while the calculations process. Please note that at this time the Astroid App should be left open in this state to ensure the calculations run to completion, however, users may open additional instances of Astroid and work on other plans while these calculations proceed (no performance issues should be encountered when using multiple instances since the "heavy" calculations are off-loaded to the cloud calculation servers).

During the calculation process the user may check to see the status of the calculations. The example below shows a Feasibility calculation that is 4% complete. As calculations finish the user will notice this number increasing.
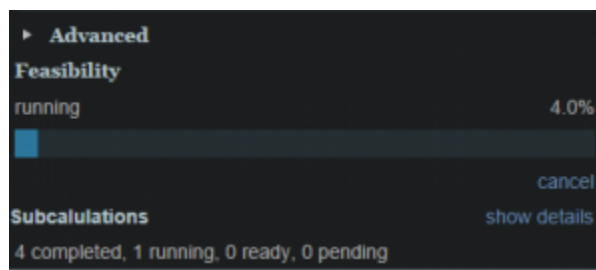
By clicking on *Show Details* a detailed list of what calculations have been finished and which are running will be displayed. In the example below the dij's are completed and the Feasibility is currently running. In the detailed view if the user chooses *show completed subcalculations* they will be able to obtain the identification number of each calculation.
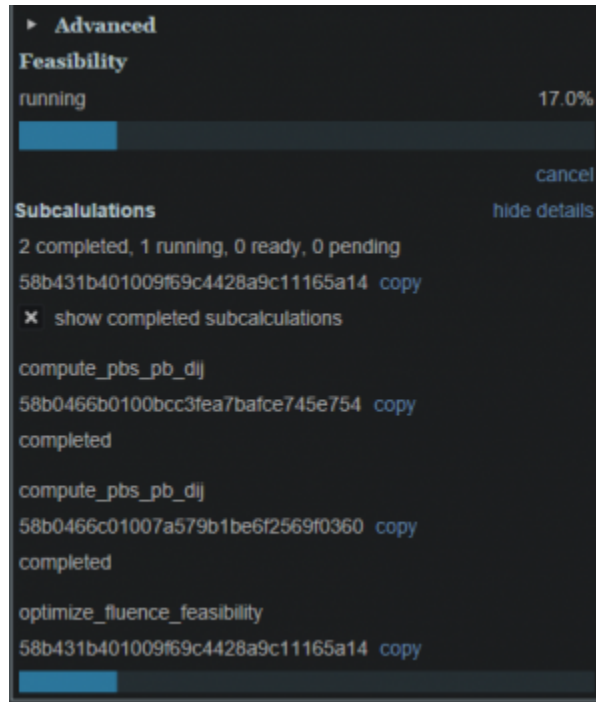
Dose Normalization and Display

The user has many options for how the dose is displayed in Astroid. The options for controlling the display of the dose are on the right hand side of the display under *Dose Options*. The *Dose Options* provide controls over the DVH type (relative or absolute volume), the colors and scaling of the display dose, the type of dose display shown (colorwash, isolines, or isobands), as well as the scope of dose to display (full plan, single fraction group, or individual beam dose).

Dose Volume Histogram (DVH)

Relative and Absolute DVH

The planner has the option of viewing the dose for the DVH in relative volume (dose per percentage of the volume) or in absolute volume (dose per cc of the structure) using the *Absolute DVH* option. The user may also hover over any area of the DVH curve to obtain the dose and percentage of a given structure or click on one or more lines to start tracking the cursor value for the lines.
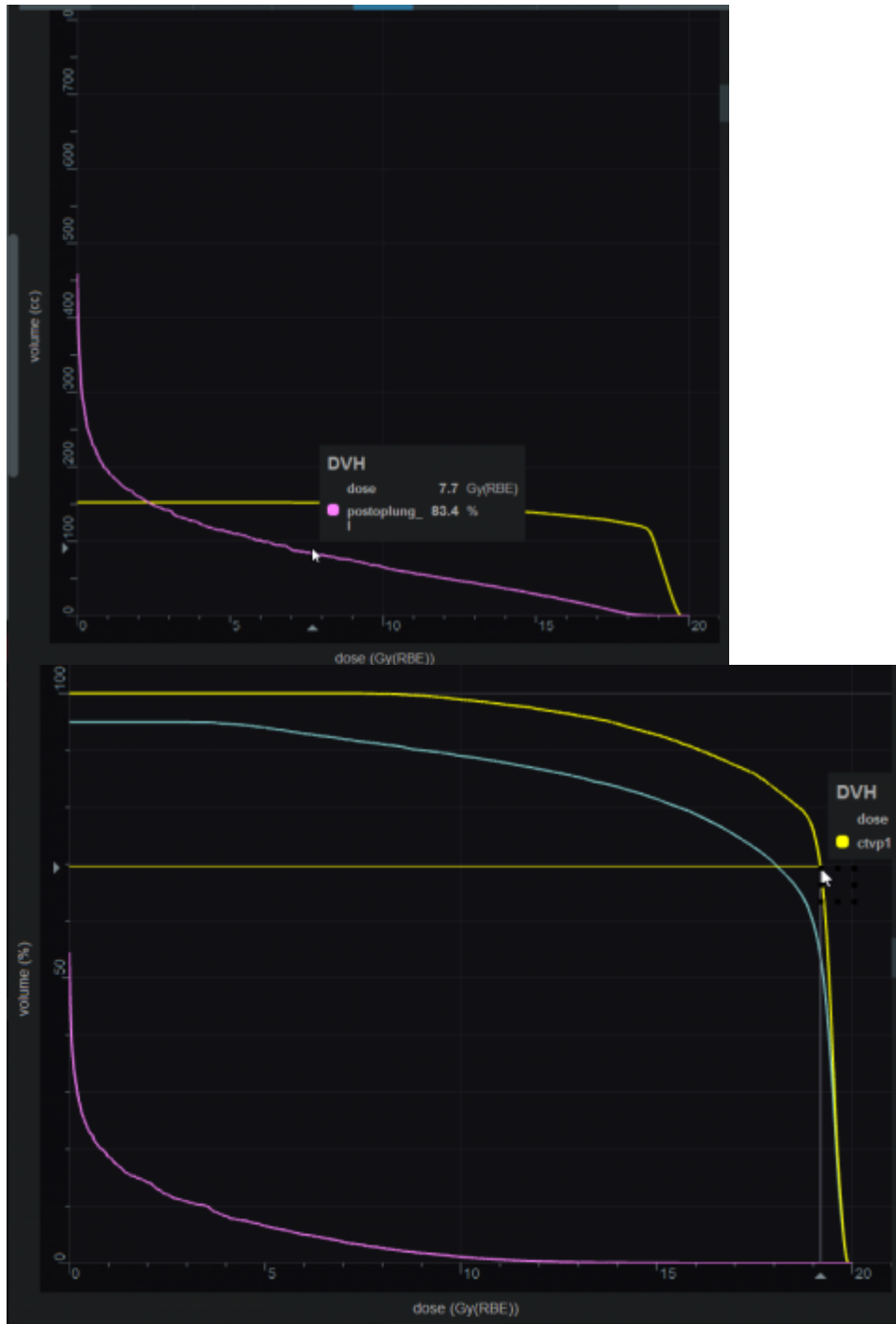
Dual Dose DVH

The planner has the option of viewing the original MCO dose and the currently navigated MCO dose in the DVH graph. By selecting the *Show Secondary Doses* option under the Dose Options, the DVH graph will display the following doses:
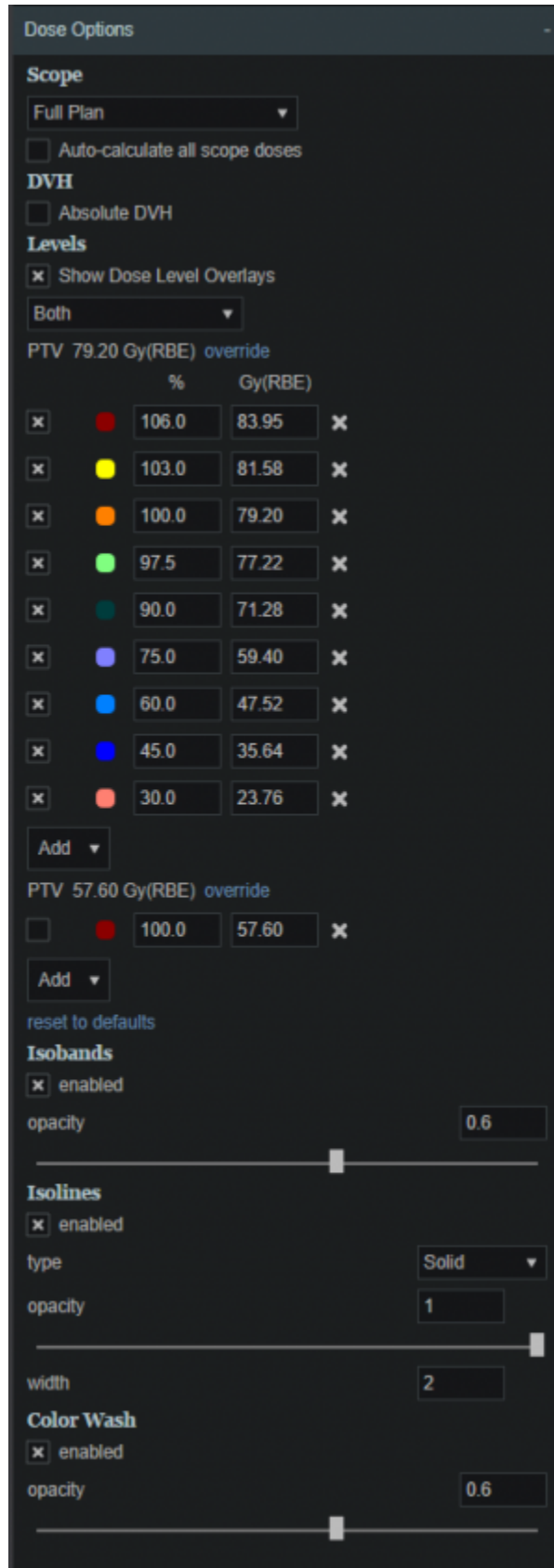
- **Dotted Line:** Original un-navigated dose.
- **Solid Line:** Current navigated dose based on the position of the MCO sliders.

With the *Show Secondary Doses* option disabled, only the current navigated dose will be displayed within the DVH graph.
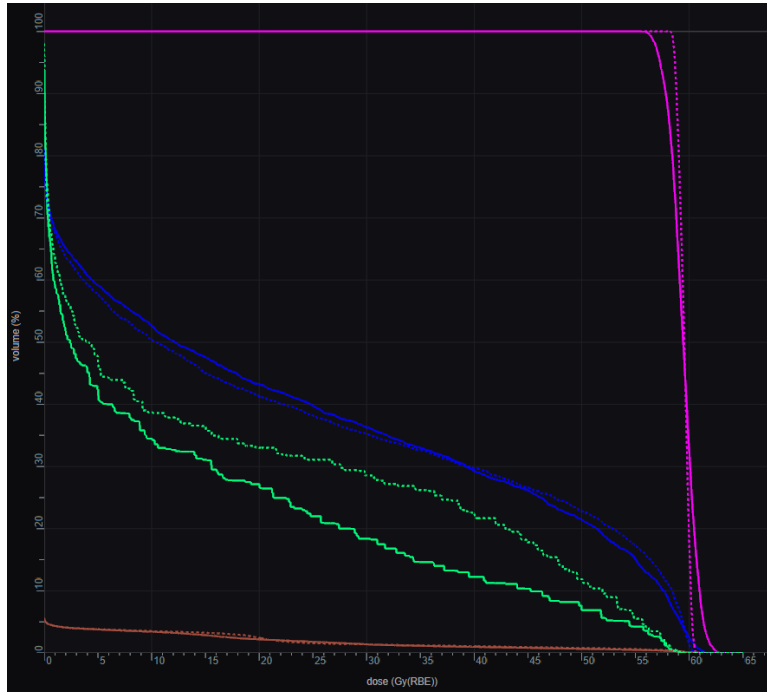
Dose Display Normalization

As in the DVH the user has multiple options for displaying the dose. The user may change the percentage isodose line and its corresponding Gy they would like displayed. This is done by entering the appropriate numbers in the boxes under *Levels*. The user may turn on and off specific levels by clicking on the *X* to the left of the line. The user also can choose to view the dose as either isobands, isolines, color wash or combinations of these. The user may use the sliders to set the opacity for each of these as well. They may choose the line width and whether it is solid, dashed or dotted for isolines.

Dose Options   ·

Scope

Full Plan   ▼

☐ Auto-calculate all scope doses

DVH

☐ Absolute DVH

Levels

☒ Show Dose Level Overlays

Both   ▼

PTV 79.20 Gy(RBE) override

		%	Gy(RBE)	
☒	🔴	106.0	83.95	✖
☒	🟡	103.0	81.58	✖
☒	🟠	100.0	79.20	✖
☒	🟢	97.5	77.22	✖
☒	🟢	90.0	71.28	✖
☒	🟣	75.0	59.40	✖
☒	🔵	60.0	47.52	✖
☒	🔵	45.0	35.64	✖
☒	🔴	30.0	23.76	✖

Add ▼

PTV 57.60 Gy(RBE) override

☐	🔴	100.0	57.60	✖

Add ▼

reset to defaults

Isobands

☒ enabled

opacity   0.6

Isolines

☒ enabled

type   Solid   ▼

opacity   1

width   2

Color Wash

☒ enabled

opacity   0.6

In the case of a plan with multiple *Fraction Groups* the user may choose to view the dose:

1. In a composite dose- *Full Plan*- which will take into account all *Fractions groups*

2. For a particular *Fraction Group* or
3. For an individual beam

To pick one of the above the user must choose from the dropdown list under *Scope*. The *Scope* automatically defaults to *Full Plan*.

Note: When in a sliced image display containing dose, slice scrolling positions will be based on the smallest voxel size of the calculation grid. For any sliced image displays that do not show dose, scrolling positions will be based on the CT image slice thicknesses directly.
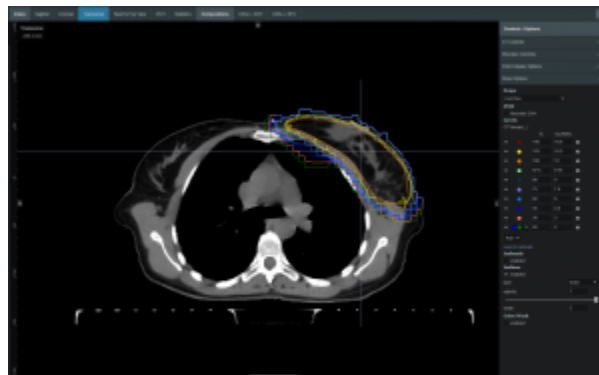
Isobands

Isobands are an interpolation of dose from isodose line to isodose line. Isobands take a range of interpolated dose and fills it in with color.
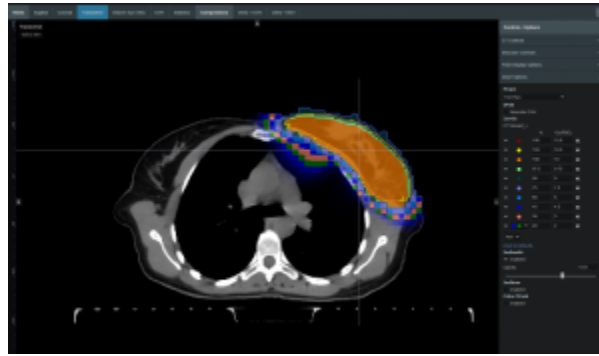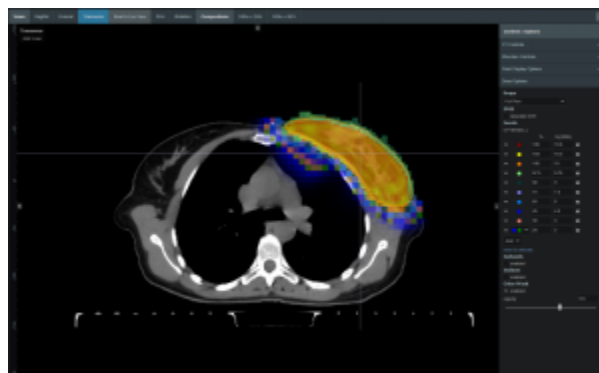
Isoline

Isolines display either the absolute or relative dose in the form of closed lines of constant dose value (i.e. these are lines that pass through the points of equal dose).
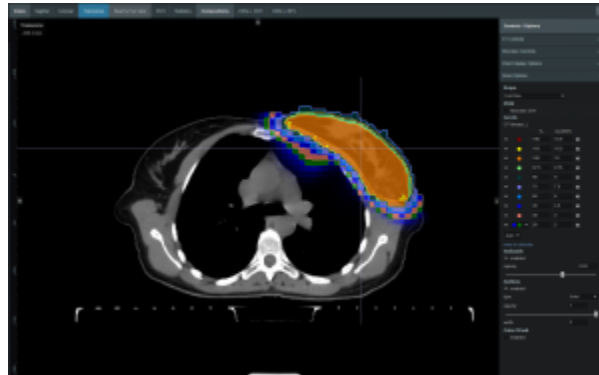

Color Wash

Color Wash shows the raw dose across the given range of values, blending colors according to the dose levels.


Combination

The user does have the ability to combine multiple representations. Below shows a combination of Isobands and Isolines.

Navigating the Solutions

Once the plan has been calculated the *Navigation* block will become active. This block contains entries for all the active objectives and under each objective is a slider bar. This slider bar allows the user to adjust the importance of an objective and to see, in real time, how the change will affect the dose to the patient.

The Navigation Sliders should provide an intuitive process for finding the optimal plan, but by gaining a complete understanding of the Navigation Sliders users will be better equipped to quickly reach their plan goals. It should also be noted that sliders for minimize objectives will slide to the left and sliders for maximize objectives will slide to the right. On each slider there are two vertical bars. The thick white bar is the user controlled slider handle and it represents the worst value of an objective that the user wants to allow. Simply stated, the objective will not go past this limit. The thin blue bar denotes the actual current value of the objective. Astroid calculates this value by balancing the solution over the available ranges of each objective. It should now be clear that moving a slider does **not** directly set an objective, but rather it places limits on the allowable range of an objective. It is this feature that makes navigating the solution space very clear and effective.
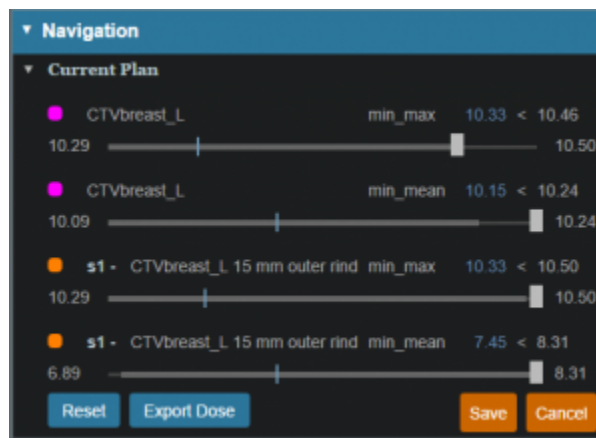
The blue and white numbers to the upper right of each slider correlate to the objective value for the current plan and the objective limit based on the slider position, respectively. So in the image above, it can be seen that the top slider has been set such that allowable maximum dose to the CTVbreast_L is 10.46 Gy(RBE), but the current value is 10.33 Gy(RBE). The numbers at the end of each slider bar denote the overall range for the objective value (i.e worst and best possible values). The main slider horizontal bar is also separated into two sections. The thicker, lighter grey horizontal bar is the range or window

that the objective is currently limited to stay within (it is limited due to the positioning of all sliders by the user). The user will notice as they drag the slider handle (white bar) on one objective, this light grey area will change on some of the other sliders. This allows the user to know the limits they have to work in and the impacts (trade-offs) that one objective is having on the others. Sliders should be adjusted such that all physician goals are achieved and the best balance of target coverage and normal tissue doses are realized for the unique patient at hand.

All of these adjustments are able to be done without running a new plan as would needed to be done in traditional treatment planning systems. This allows the user to look at many different solutions in a short amount of time.

If the user likes the adjustments that were made to the sliders they may click the *Save* button in the bottom right hand corner. This will save the objectives at their current position. If the user does not like the adjustments they have made to the sliders, they may hit the *Reset* button to reset all the objective sliders to their last saved state. The *Cancel* button will close the *Navigation* block in its current state.

2016/08/17 13:00

Beam Delivery (SOBP)

SOBP Fraction Groups

Defining *Fraction Groups* is the final step in the SOBP planning process within Astroid. A fraction group is simply an arrangement of beams that will be used in a typical daily treatment fraction. The Fraction Group contains a list of beams where each beam can be weighted and normalized based on the needs of the patient at hand. Beam normalizations allow for minor field independent adjustments of dose and these factors are limited to stay within 0.90 - 1.10. Beam Weights established the relative fluence of each beam within the fraction group and therefore the sum of the beam weights in each fraction group must be 1.0. Further details of defining fraction groups are provided below.
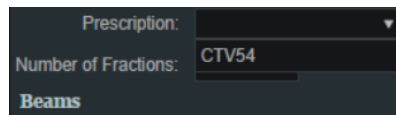
- To get started, navigate to the *Beam Delivery* block and click *Create New Fraction Group*.


General Fraction Group Data
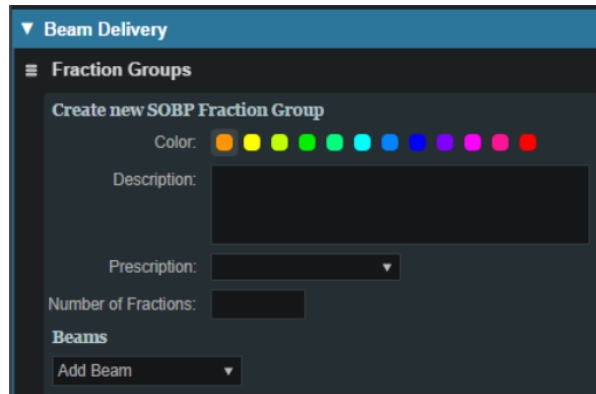
- **Color**: Display color of the *Fraction Group*
- **Description**: Optional, user specified text describing the *Fraction Group*
- **Prescription**: Prescription that the *Fraction Group* implements


- **Number of Fractions**: The total number of fractions to be delivered for this *Fraction Group*; this is very important as it will determine the appropriate dose to be delivered from this fraction group, which when combined with the beam weights, provides the proper Monitor Units to be delivered for the individual beams
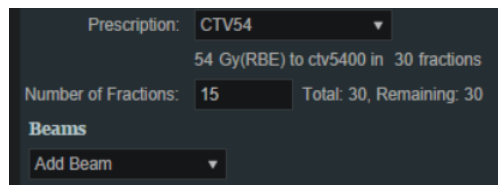

Beam Options

- Select the beams to be added to this fraction group from the drop down list. Repeat this process as necessary. Notice how one of the beams in the image below is grayed out. This means that the beam has already been selected or it is a *patch beam*. If it is a patch beam, the beam will automatically be added with its parent beam. There is also the option to create a new beam from the drop-down list.
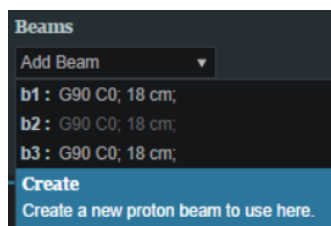
- Change the normalization factor (if desired) by clicking its box and entering the value desired.
    - This is independent from the weight values

- Available as an option for patch beams
- Useful when adjusting hot or cold areas where beams treat the same area or meet
- Weight each beam by either sliding the slider or clicking on the weight value box and typing in the value.
  - The value of all beams listed **MUST add up to 1.0** (100%)
  - By default, the beams are automatically weighted evenly, and, if edited, can be reset by clicking the *weight beams evenly* option.
  - Use the *Beam Lock* (not available for patch beams) to restrict a beam from automatically adjusting when another beam's weight is adjusted. This option is useful to secure one beam's weight while adjusting the other beams' weights (see image below). The sum of all weights still must equal 1.0.
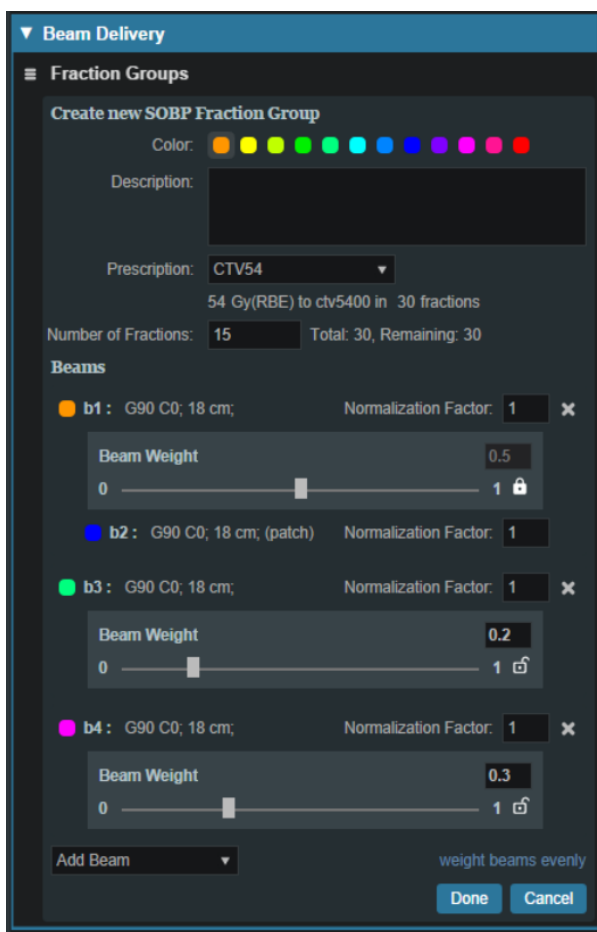
- When finished, click the *Done* button. Clicking the *Cancel* button will reset the changes made to the current fraction group and return the *Beam Delivery* block to its previous state.
- Repeat this process of adding fraction groups until all remaining fractions are completed.

2019/08/15 14:17

Plan History

Since the Astroid system captures and stores the user inputs (rather than the results), it is able to maintain an exhaustive history of all edits made to your data with relatively low storage needs. Users are

able to benefit from this information through the *Plan History* feature that is available within each treatment plan. The *Plan History* is a feature that allows the user to see and explore all the changes and modifications made to a plan. Each modification to a plan will result in a new *Revision* of the plan (note: in a complex plan there may be hundreds of revisions). If the user is not satisfied with the results of a modification they may go back to any of the previous revisions and restore it to the active instance (note: this will cause another *Revision* to be created for the reversion). Below is a walk through and more detailed explanation of this feature.

1. Open the *General* block from the Plan Overview and the History item can be seen at the bottom of this block
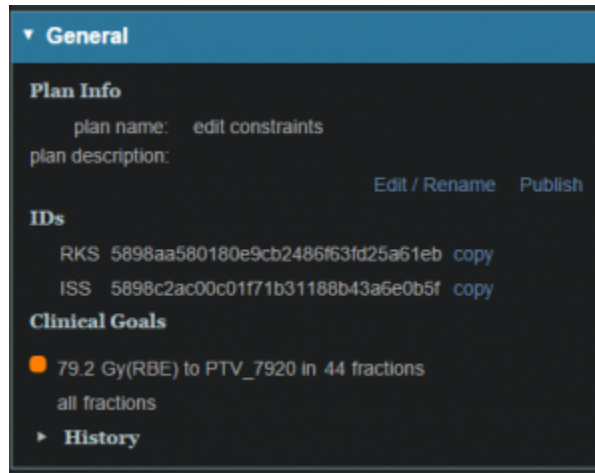
2. The summary of the latest revisions will appear in the right display pane
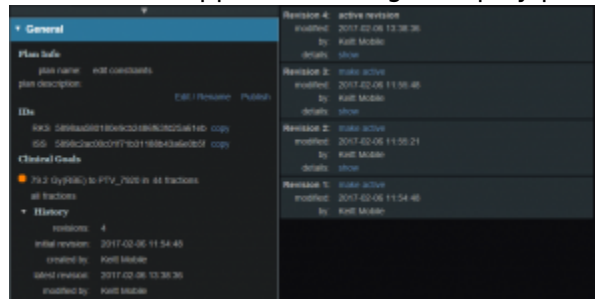
3. Expand the *History* details by clicking the small arrow (this is not mandatory)
    1. The number of plan revisions will be listed (In the above example there are 4 revisions)
4. The user can now review the various revision summaries
    1. Clicking the blue *show* link will expand that particular version of the plan and explain what was changed
    2. "op": is the operation performed in this version that differs from the previous version (e.g. insert: an item was added)
    3. "path": is the item in the treatment plan data that had the operation performed (e.g. points: a point geometry was changed)
    4. "val": is the value of the data that was changed (see image below for the "val" of an added point)
5. If the user would like to return to this version they may do so by clicking the blue *make active* link
6. The user can close the expanded version by clicking the blue *hide* link

Revision 4:   make active
    modified: 2017-02-06 10:55:52
          by: Keitt Mobile
     details: hide
                ID: 58989c8800c0f95d8d6498ac484c1a44 copy
                {
                  op: update,
                  path: [next point id],
                  val: {
                    some: 2.0
                  }
                }
                {
                  op: insert,
                  path: [points, 1],
                  val: {
                    some: {
                      geometry: {
                        centroid: {
                          snapshot: {
                            directive: {
                              site: Prostate
                            }
                          }
                        }
                      },
                      properties: {
                        color: {
                          b: 1.0,
                          g: 128.0,
   r: 255.0
                        },
                        description: ,
                        type: isocenter
                      }
                    }
                  }
                }
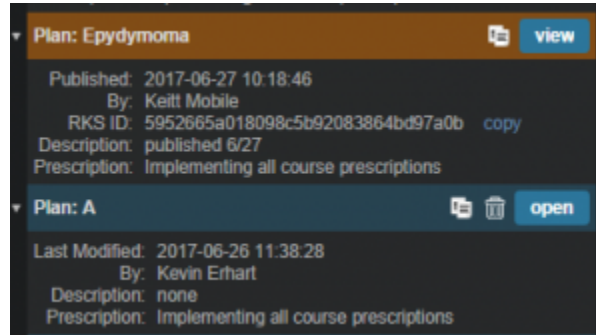
2016/09/20 16:57

Plan Publishing

Once a physician has approved a plan it should be *Published*. *Publishing* a plan allows the user to lock the plan. This means that once a plan has been *Published* no changes may be made to that plan. A plan that has been *Published* will be available to "view only". The *Plan History* will show the date and time a plan is *Published* as well as the user who *Published* it. A plan may not be changed or archived once it has been *Published*. If a user needs to make a change to a *Published* plan they will need to copy the *Published* plan in order to do so. Once the *Published* plan is cloned they may proceed to make any changes desired.

The following steps outline how to publish a plan in the Astroid Planning App:

1. Open the *General/History* block from the Plan Overview
2. Select the *Publish* button
3. You can edit the Plan name and description at this time if needed

▼ **General / History**

| Name: | Epydymoma |
| Description: | published 6/27 |

Publish   Cancel
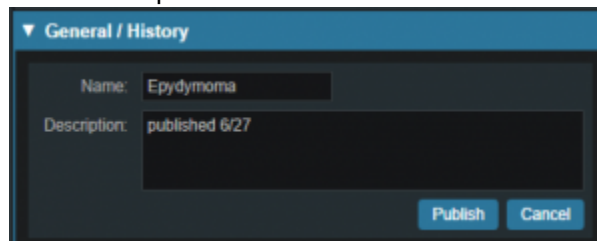
4. Once the information has been filled click the *Publish* button
5. The plan will now be denoted as Published in the *Patient Overview* and users will only have the ability to view or clone the plan

2016/09/20 16:57

Displays

This section contains general information regarding the various displays available in the Astroid Planning Application. During most tasks, there is a top bar that contains a list of available single and composition views. In most instances these include standard two dimensional sliced views: transverse (axial), sagittal, and coronal. Additional common views include: three dimensional view, Beam's Eye View (BEV), and Dose Volume Histogram (DVH) View.

Beam's Eye View

The Beam's Eye View is a projection of the three dimensional beamline and patient structures into a flat plane as viewed from the beam's proton source. Since certain proton machines may not have a single source point, the BEV supports a dual source projection process as described for aperture devices in the following article, but this is equally applicable to all patient and beamline entities. All projection for the BEV are done to the isocenter plane, therefore all distances measured within the application in the BEV are as projected to isocenter.

2017/08/10 19:18

Plan Templates

Plan Templates are a powerful feature of Astroid that can greatly reduce the time spent in creating high quality treatment plans. In a simple sense, a *Plan Template* is just a starting point that can be used when creating new treatment plans for this or other patients. When a *Plan Template* is applied during new plan creation (see here for creating a new plan), all user specified plan parameters from the template are copied into the new plan. In essence you are applying the plan to a new set of images and structures, therefore it is important that structure names and other data are consistent in your *Patient Models* when using *Plan Templates*.
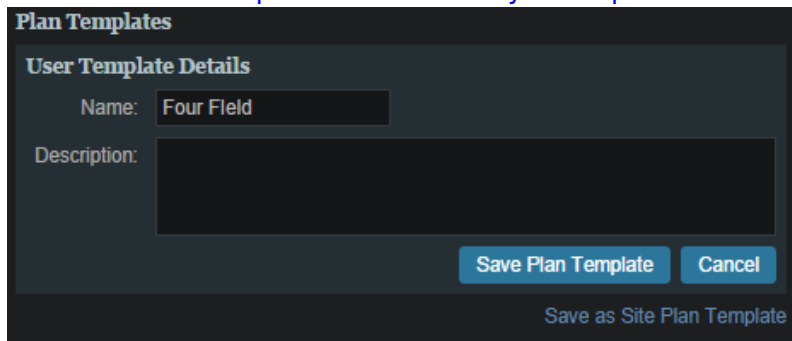
Saving Plan Templates

Plan Templates can be defined globally at the site level for all users at your institution and each user is

also free to create their own private list of user level *Plan Templates*. A *Plan Template* can be easily created from any existing plan by opening the General/History block. At the bottom of this block the user may then choose either *Save as User Plan Template* or *Save as Site Plan Template*.
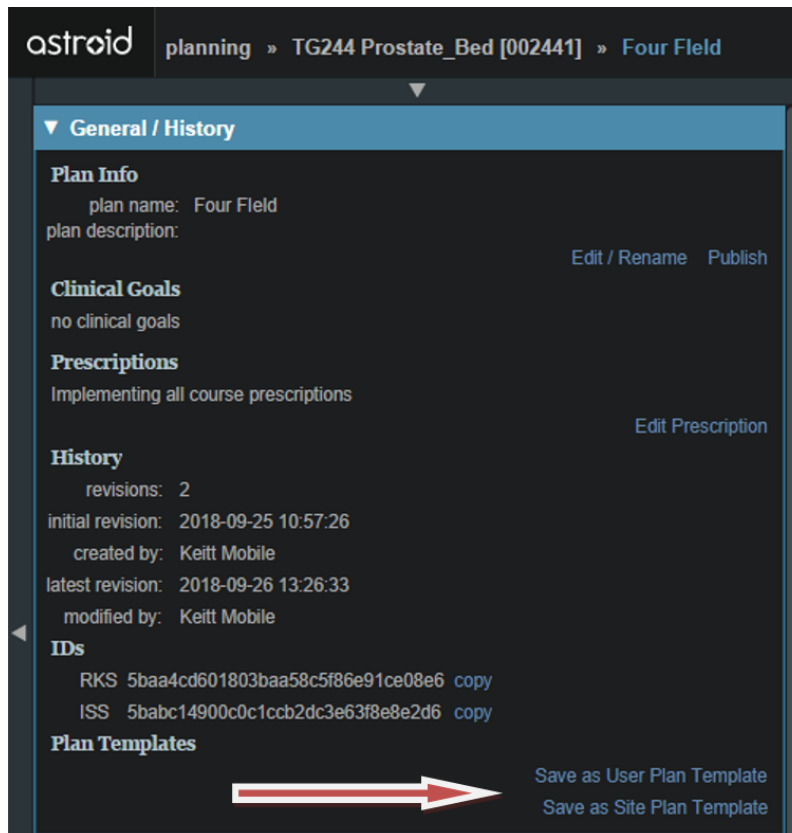
The user then provides name for the Template and fills in any description information as desired.

When saving an existing plan as a template, there are a few rules/tips that should be kept in mind which will help make your templates easier to use in the future:

- In order for templates to work well there needs to be consistency in use of structure names (e.g.- Brainstem consistently labeled Brainstem, not brainstem, Brain stem, brain_stem etc.). Note that proper and consistent use of *Site Structure Templates* is a great way to ensure this is adhered to by all users.
- Most Astroid Plan parameters reference data that will change properly when applied to a new *Patient Model* using a *Plan Template*, however, care should be taken when using *Explicit Points* as these include fixed coordinate values that they may not transfer as desired from plan to plan. avoiding the use of *Explicit Points* is the best practice for *Plan Templates*, but if they must be used be sure to check each explicit point in the new plan after applying a template.

- *Plan Templates* are specific to the *Site Structure Template* used by the *Patient Model*; therefore if a template is created for a prostate patient, for example, that template will not show up for a breast patient due to the *Site Structure Template* selection being different.
- Keep in mind that a *Plan Template* can be created to any level of completion desired within the planning process. For example, a simple template could be created that adds only a few planning structures (e.g. rinds, expansions, etc) or a complex template could be saved that includes all plan data including the full optimization constraints and objectives. Different disease sites may lend themselves to different levels of detail in the *Plan Template* so users are encouraged to explore different options to determine what works best for their clinical workflow.

Using Plan Templates

Plan Templates are applied when creating a new plan:

1. Click on the blue *Add Plan* link under the *Patient Model* to create a new plan
2. From the *Base Plan* drop down menu choose the *Plan Template* that should be used and then click OK
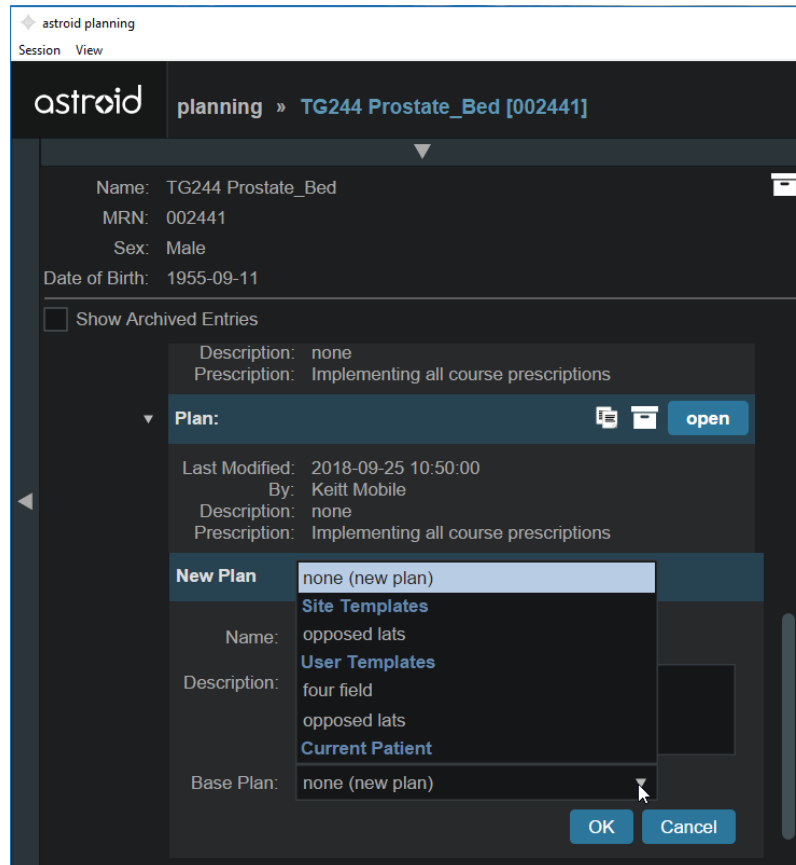

3. Open the new plan and check that all plan parameters have been applied as expected (pay special attention to *explicit points* as described above)
4. Make any changes necessary within plan and then proceed with planning from this starting point
5. If used well, you should be able to review the plan, make a few minor edits, and be at the point of running feasibility & optimization much faster than when starting from scratch

2018/09/26 16:53

Plan Export

The *Export* Block is available in Astroid to allow for saving patient and plan information in DICOM file format. Typically this feature is used once a plan has been completed, the physician has approved the plan, and the plan is ready to be sent to the Record and Verify system for QA and then patient treatment. The process of exporting files and the options available to the user are described below.

- Open the *Export* block.
- If the plan is unpublished (unapproved), then a qualified person must authorize the export of this plan by checking the appropriate check box in order to perform the export
- The user can choose from the following items to export:
    - RT Structure Set
    - RT Ion Plan
    - RT Dose
        - Plan (total dose for all fraction groups and all sessions)
        - Fraction Group (dose for all sessions of a single fraction group; each fraction group is exported to its own file)
        - Beam (dose for a single session from a single beam; each beam is exported to its own file)
- The export location is then set as either a local directory or to a DICOM server (AE title)
    - If exporting locally the choice to anonymize the data can be made by checking the *Anonymize patient data* box option as shown
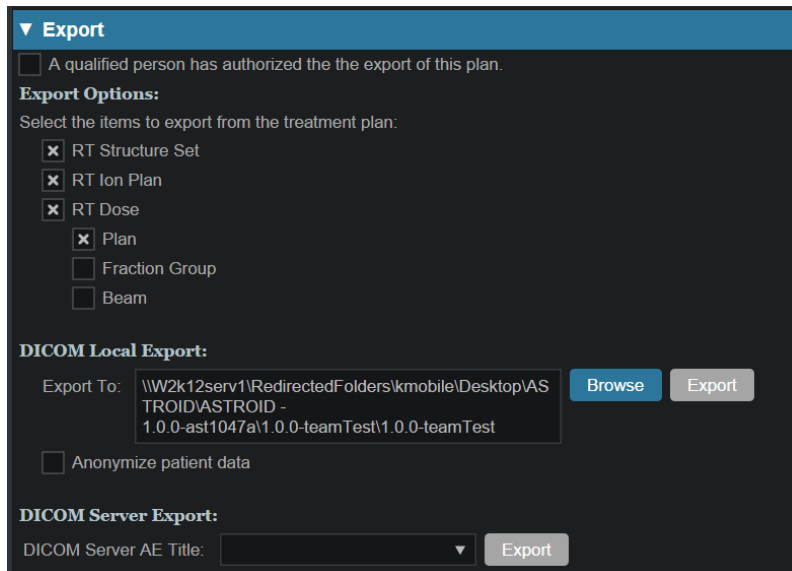
- When exporting to a DICOM Server, several options are available
    - Preset AE Titles which are managed through the *Site Configuration* can be selected or the custom option is available in which a specific server name, location, and communication port ID will need to be specified

2016/09/20 16:57

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Last update: **2019/08/26 14:43**

Walkthroughs

Overview and Purpose

These walkthroughs are intended to be easy to follow step-by-step guides for creating plans using Astroid. There is a simple prostate patient, which is then followed by a complex head and neck plan. In many cases specific prescription, constraint, and other dosimetric values are given to use as input. It should be noted that these values are not intended to provide clinical guidelines and should in no way be considered a recommendation for values that are appropriate for clinical use. The intent is that after completing these walkthroughs, you will have gained an understanding of many of the details and much of the information that will be required to generate a complete Astroid treatment plan. Armed with this information and knowledge, you will then be able to complete the process using the clinical protocols and requirements from your facility to generate clinically appropriate patient treatment plans using Astroid. Additionally, since many of these parameters and items are dependent upon one another to produce high quality treatment plans, it is recommended that you follow along exactly in order to produce similar results. Once you have gained comfort and understanding of the various planning parameters, then it is encouraged that you modify the parameters and explore their impacts to gain additional familiarity with the system.

## Prostate Plan Walkthrough

Launching Planning

1. Open the Astroid Launcher and login
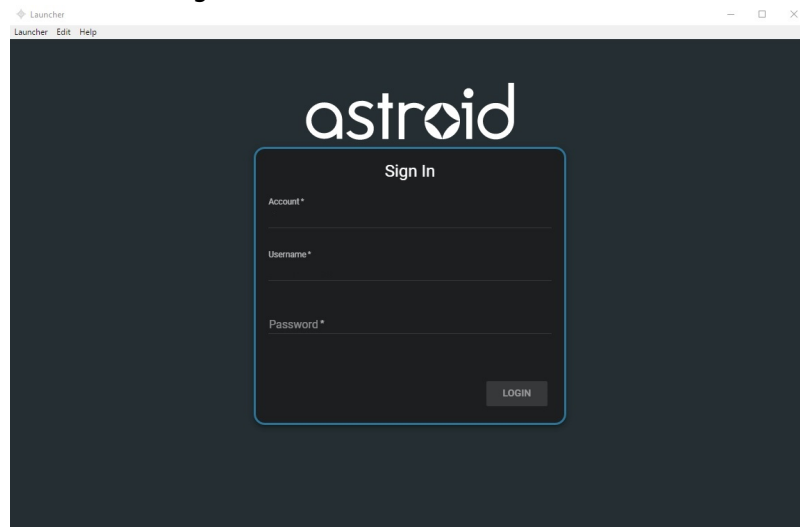
2. Select your realm
3. A list of available apps will be listed on the left, select *Planning* from this list
4. If you see an Install button click it and wait for the version to install. You will know it is installed when you see a LAUNCH button
5. Click the LAUNCH button. The version of planning that is installed in your realm will now open

Creating a Patient

1. From within the Planning App click on the Imports block
2. Select the CT image set (SBRT Prostate) from the list of available files for import
3. Ensure that the MRN is correct
4. Click the *Create Patient* button to start the import process
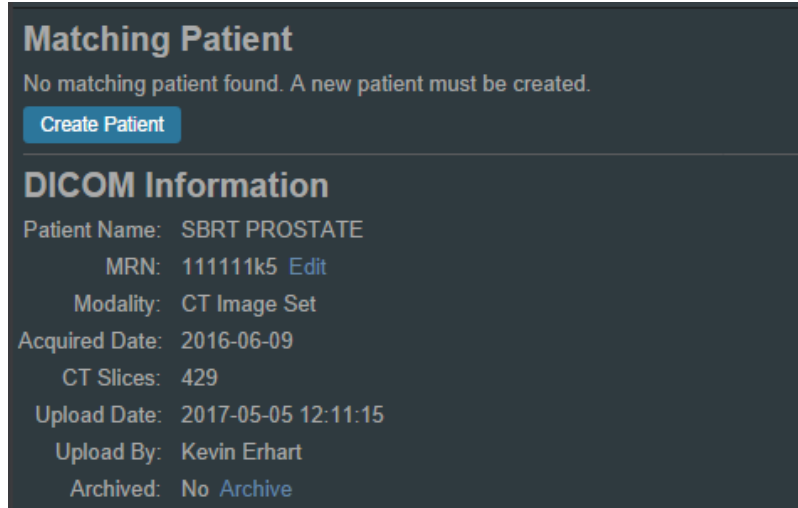
5. In the control pane on the left hand side, the patient model will be automatically selected based on the structure set DICOM UID information
6. Fill in the Patient Data and select the appropriate treatment site and HU to RSP curve (as shown below)
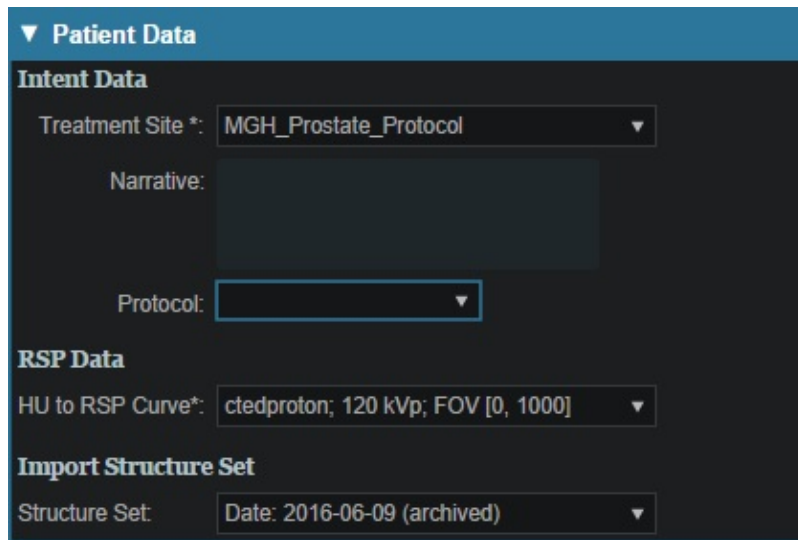
7. You will see a list of the imported structures. Here you may choose whether or not to import each structure by checking or unchecking the box beside each structure name.
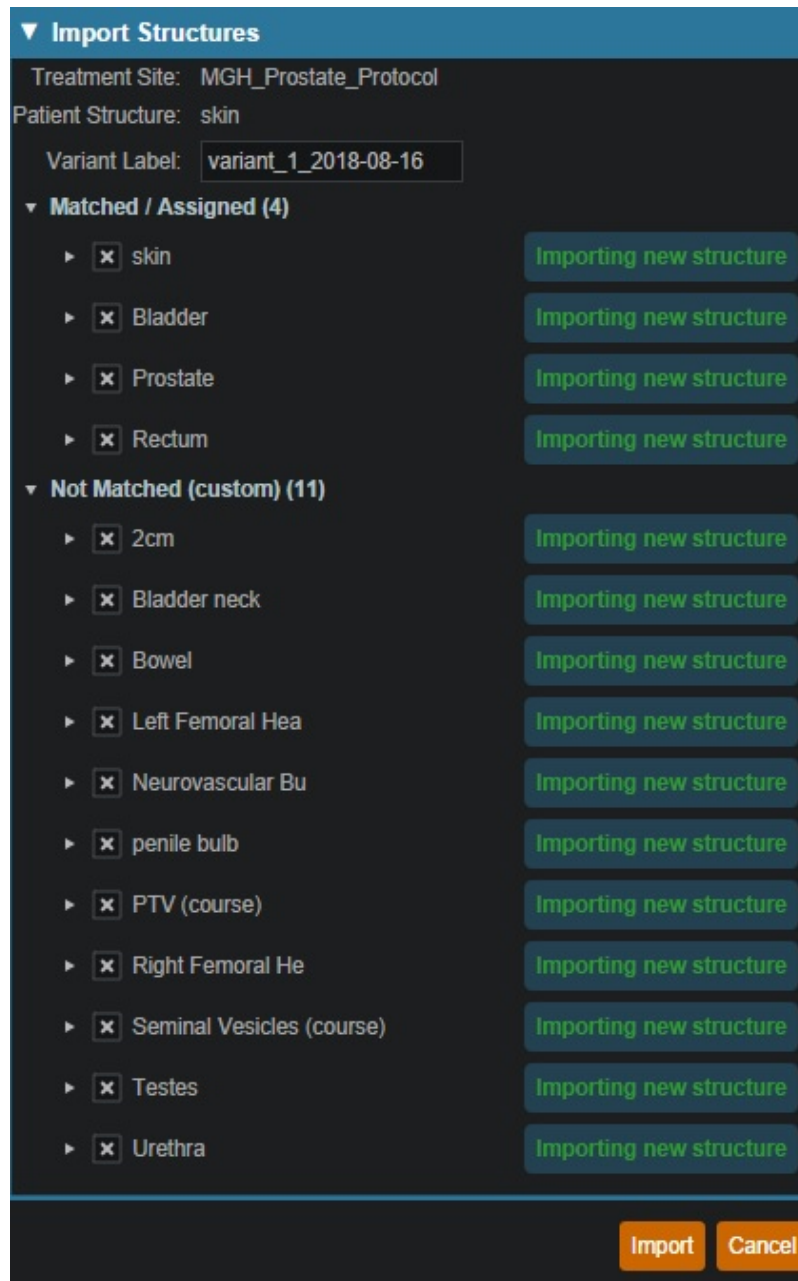
1. For this case, we will import all available structures and there is nothing to change on this page
2. You also have the ability to assign or edit any structures that are shown as *custom*, which indicates the name did not exactly match a site structure from the treatment site template list you specified during patient creation
3. Matched, Assigned, and Custom structures are designated with corresponding tags at the end of the structure name in the structure list.
4. Assigning a custom structure to a defined site structure will result in the imported structure inheriting all the predefined structure properties (e.g. name, type, color)
5. For all custom structures the type is by default set to "Other" unless it contains the letters "TV" (as in PTV or CTV), in which case it is assigned the type of "Target"; this may be changed here if needed

8. Click the *Import* button to create the patient and import the CT Images and Structures into it
9. The patient is now created and all available data has been imported, so it is time to proceed with entering the prescription information

10. Click on the *Open Patient* button

Course Prescription

Prescription information is stored in the *Course* and must be added prior to making a treatment plan for a new patient.

1. Open the patient after importing the CT and Structure Set
2. Open the Patient Course (note: it will automatically open if the patient is freshly created)
3. Next proceed to *Prescriptions*
    1. Select *Create New Prescription*
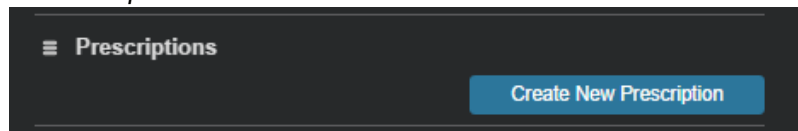
    2. Select PTV from the Prescription drop down menu
    3. For this example the dose will be 79.2Gy in 44 fractions to the PTV (as shown below)
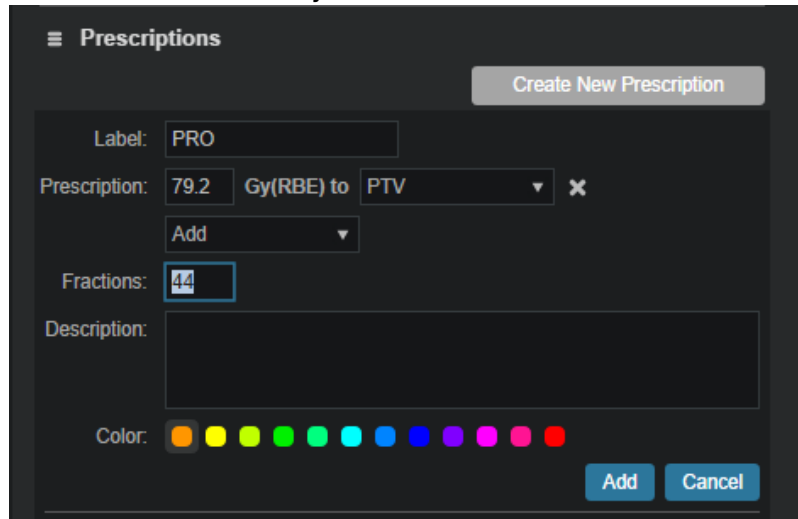
    4. *Label* and *Description* are free text fields that allow you to "name" each Prescription and provide any description or notes necessary to distinguish between each in the case of multiple prescriptions. You must enter a "name" in the *Label* in order to proceed. You are free to enter your own values in these fields for this walkthrough. Click *Add* when completed
4. Fill in the *Clinical Goals*
    1. Choose the structure from the dropdown to add your goal
    2. In this example we will set a minimum dose to the PTV at 79.2Gy and the maximum dose at 85.5Gy as shown below
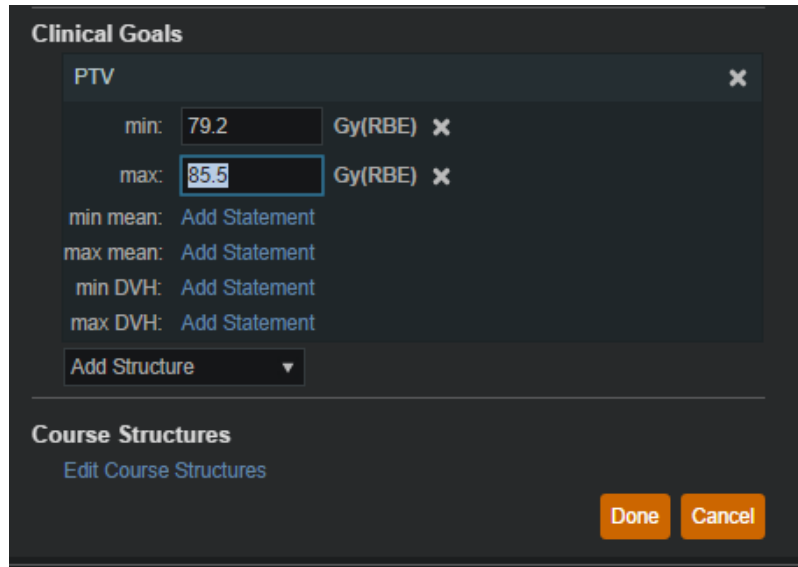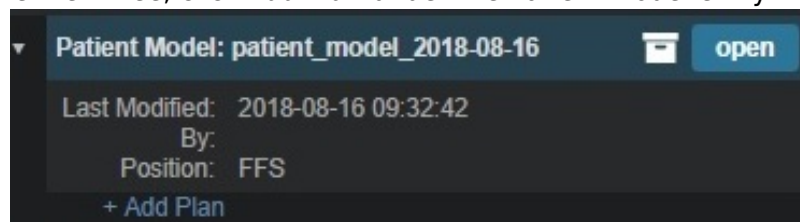
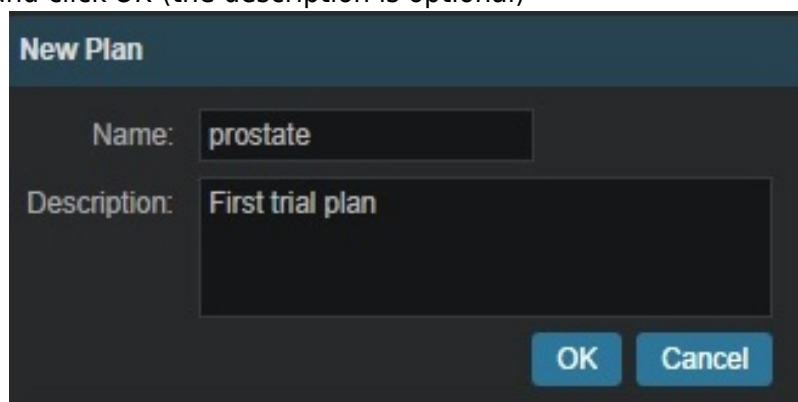5. Click *Done* to complete the *Course* editing

Plan Creation

The required *Course* and *Patient Model* information was selected during import, so now we can move to creation of a treatment *Plan*

1. From the Patient Overview tree, click *Add Plan* under the Patient Model entry

1. Name the plan and click *OK* (the description is optional)

2. This creates an empty plan with its prescription set to fulfill all portions of the Course Prescription
2. Now open the new plan by clicking the *Open* button under the new plan entry in the Patient Overview tree

Plan Prescription Implementations

1. Click the *General / History* heading to expand this block
   1. Notice here that our empty plan starts out with its prescription set to fulfill all portions of the Course Clinical Goals and Prescriptions
   2. If a plan will only fulfill a portion of the Prescription, then this information should be edited to reflect this, otherwise just proceed past this block
2. In this case, we will be fulfilling the entire prescription with a single plan, so no editing is needed
3. Generating our plan will now progress to the *Patient Geometry* block, where we will create any points or planning structures that are needed (if not created in contouring software), such as a combination of the left and right femoral heads (see Structure Geometry for details on how to create structures)
4. We will create a new point to use for the isocenter (note this step is done for illustration purposes and is not necessary for most plans)

   1. Select a type of isocenter and create the point at the centroid of the PTV (as shown below)
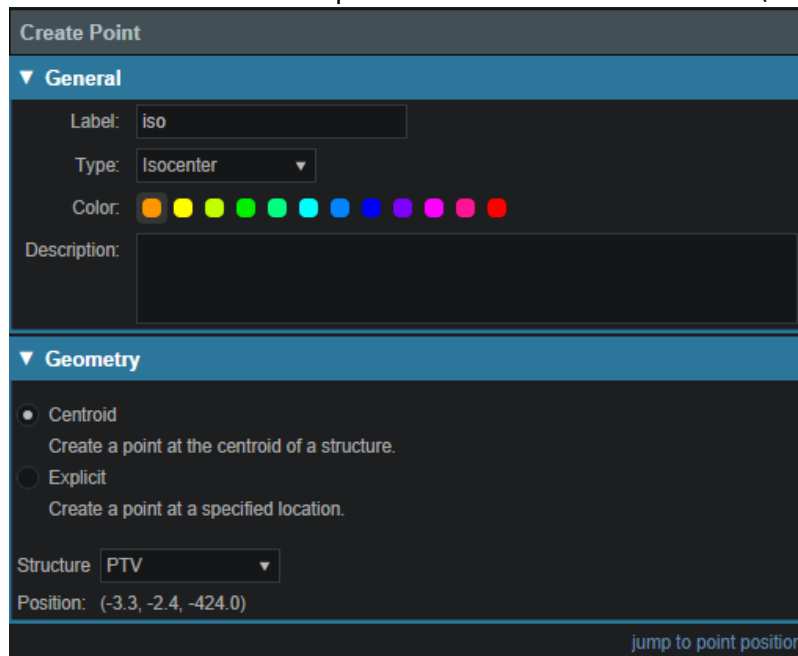
   2. Click *DONE* button at the bottom of the page

HU to RSP

Next we will move on to defining the HU to Proton Relative Stopping Power (RSP) conversion

1. Click to open the *RSP Image* block
   1. If any density overrides are needed they are entered here in the *RSP Image* block
   2. If the HU to RSP curve chosen upon patient import needs to be changed the user may do so at this point
   3. We do have any density overrides to apply for this case and the proper HU curve has already been selected

4. Click the *Cancel* button to close this block if you have already clicked on the *edit* button

Calculation Grid

We are now ready to define the dose calculation grid (see Defining the Dose Grid for a detailed explanation)

1. Click to open the *Calculation Grid* block
    1. Click the *Edit* button
    2. Create a grid by performing the following steps:
        1. Set the base grid resolution to 8 mm
        2. Click on *Add Structure* drop down menu and select the "2cm" structure then set the size to 4 mm
        3. Click on *Add Structure* drop down menu and select the "PTV" then set the size to 2 mm
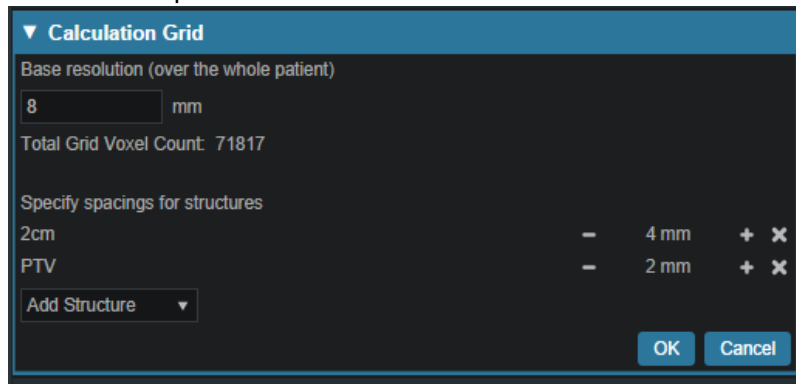

        4. The Prostate is included in the PTV volume so there is no need to set a separate grid size
        5. Click the *OK* button

Beams

We are now ready to begin defining the treatment beams

1. Click to expand the *Beams* block (see Creating a New Beam for detailed explanation)
    1. Before defining individual beams, we will first set some shared beam properties
    2. Set the *Treatment Room* by clicking on *treatment room* (this will bring up a drop down menu where the appropriate treatment room can be selected)
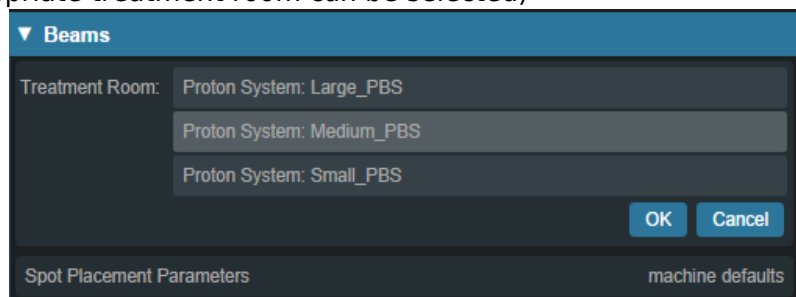
    3. Click the *OK* button
2. Click on the *Spot Placement* sub-block to set the following values (note these are the plan level

spot placement parameters, so it will apply to all our beams, unless we specifically override the values within an individual beam)
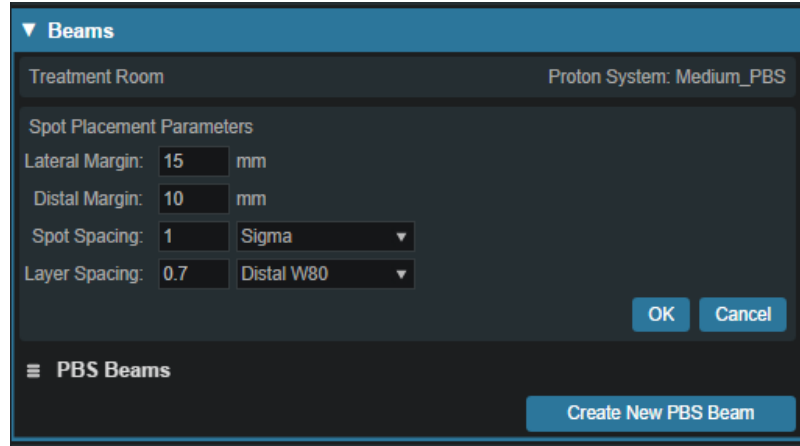
1. Lateral margin- 15 mm
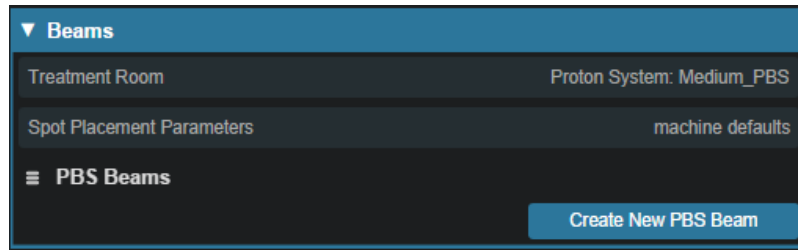2. Distal margin- 10 mm
3. Spot spacing- 1 sigma
4. Layer spacing- 0.8 Distal W80
5. Click the *OK* button

3. Now we are ready to make our beams
    1. Start by clicking *Create New PBS Beam*

1. Enter the following for each beam
    1. General
        1. Select the PTV as the Geometric Target and if desired, enter a description for the beam, for other selections leave the defaults (see Structure Geometry)
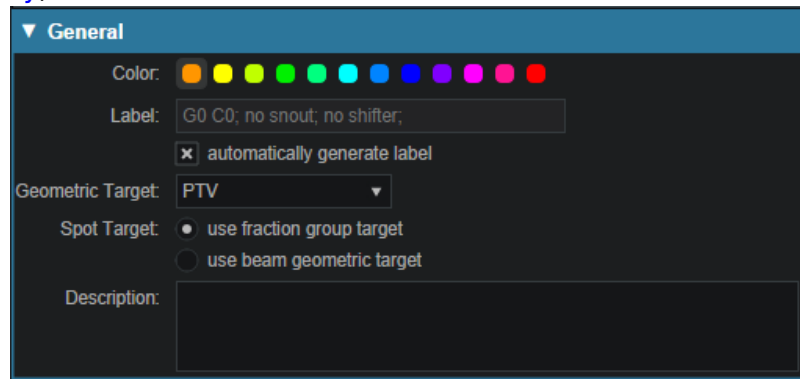
2. Approach
    1. At this point the user will specify the geometry of the beam by setting the isocenter as well as the gantry and couch angles
    2. Two beams at gantry angles of 90 and 270, respectively, will be used here, which is typical (+/- 5 degrees) for standard prostate plans such as this example

3. Couch angle of 0 is used here for each beam
    1. You may use the sliders, the +/- buttons, or simply type in the values to adjust these angles
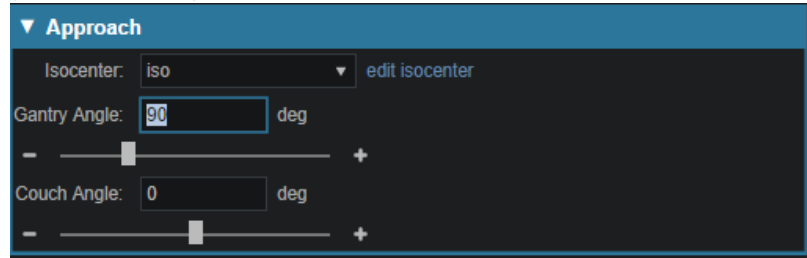
3. Snout
    1. For this example any snout can be selected

4. Aperture (if desired)
    1. If there is the need to use an Aperture for sharper penumbra the user can do so at this time (see Creating an Aperture)
    2. Note that Astroid has the ability to utilize an Aperture with pencil beam scanning for both SFUD and IMPT plans and the aperture construction will be based on the Geometric Target selection
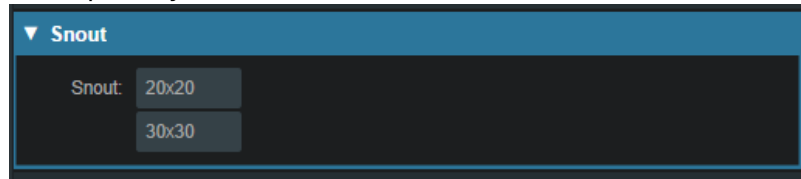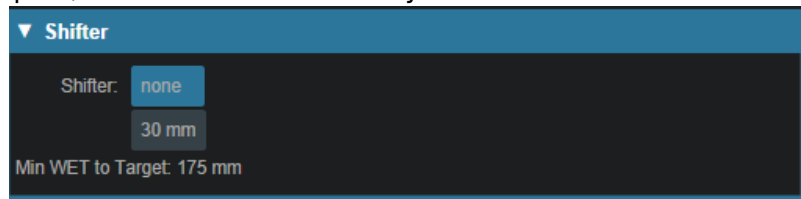   3. For this plan, no apertures are necessary
5. Shifter
    1. Simply choose a shifter from the list if one is needed
    2. For this plan, no shifters are necessary

6. Air gap
    1. The air gap is specified as the distance from the final beamline device (aperture or shifter) or the snout end if no devices are present
    2. The view automatically shifts to the 3D view when entering this sub-block and you can adjust the air gap to ensure patient collisions are avoided
    3. The default air gap is sufficient for both beams in this example
7. Spot placement
    1. Since we want both beams to use the same spot settings, we have those at the plan level and there is no need to edit the spot placements here for the beams
8. DRR options
    1. The Proton DRRs shown in the *Beam* task are generally used to help determine appropriate treatment angles
    2. In cases such as these, appropriate angles are readily determined and there is no need to utilize the DRR sub-task
        1. If you wish to explore this feature however, you may choose one of

the preset *HU Settings* from the drop down or manually set the *level, window, min HU* and *max HU* or go into *Advanced Options* for additional control of the DRR's

2. These proton DRRs are used only for visualization purposes and will have no effect on the plan construction process
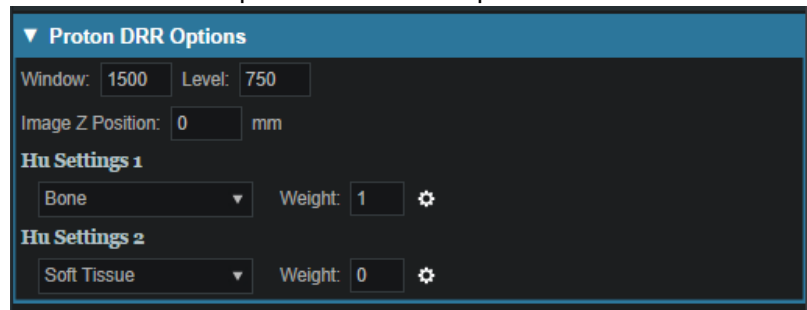
2. Click *Done* to complete the first beam

4. After creating the first beam, at gantry angle 90, it is recommended that you *Clone* it and simply change new beam's ganry angle to save time in creating the second beam at gantry angle 270 (the *Clone* button is available under a beam when it is selected for viewing from the list of beams)
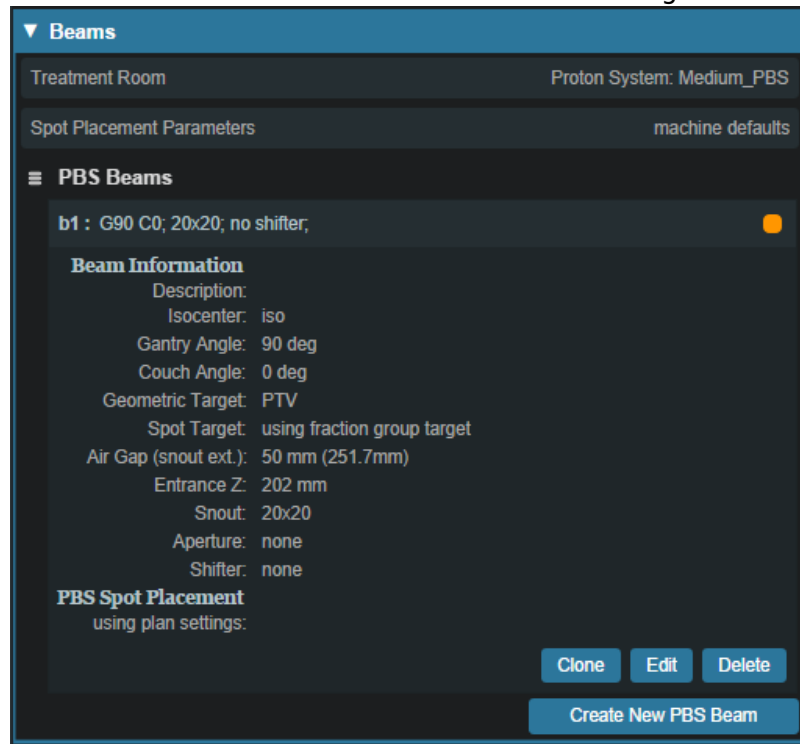
1. Once you have *Cloned* the beam choose the *Edit* button to make changes to the gantry angle
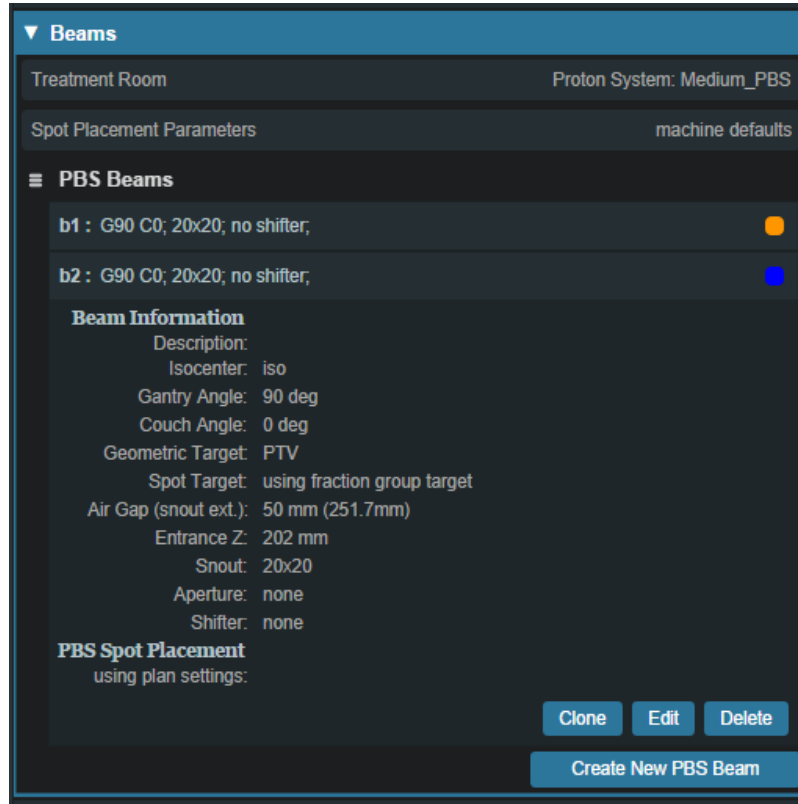
1. Note for more complex plans, there are often additional parameters to change (such as the aperture and the air gap) when creating additional beams via the *Clone* option

Optimization

With the two beams completely defined, we can now move on to organizing our treatment fraction groups and specifying the constraints and objectives for the treatment

1. Open the *Optimization* block (see Astroid Optimization for a detailed explanation of *Optimization*, *Feasibility* and *Constraints*, as well as *Running the Optimizer*)

Fraction Group

1. Choose *Create a New Fraction Group* under the *Fraction Group* block (See Fraction Groups for a more detailed explanation)
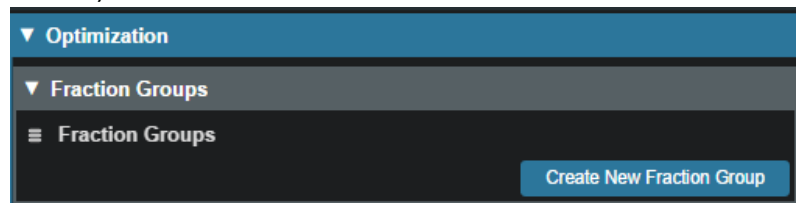
1. In the *Prescription* drop down, select the Prescription that was created earlier in the Course ("PRO")
2. Enter 44 for the *Number of Fractions*
3. Select IMPT as the *Type*
4. Set the *Target* to the PTV

5. Add both beams that were created above
6. Next to *Constraints* click the *Add Structure* drop down and choose the PTV
   1. Add a min dose constraint of 79.2 Gy (1.8 Gy per fx)
   2. Add a max dose constraint of 85.5 Gy
7. At this point your *Fraction Group* should appear as shown below

8. Click *Done* to complete the *Fraction Group*

Constraints and Feasibility

1. Open the *Constraints / Feasibility* sub-block
   1. First we will enter the *Constraints* for the planning (target) volumes and a global maximum constraint
      1. For this example do the following:
         1. Click the *Edit* button
         2. Click *Add Structure* and select (Skin)
            1. Add a max set to 85.5
         3. Click the *OK* button

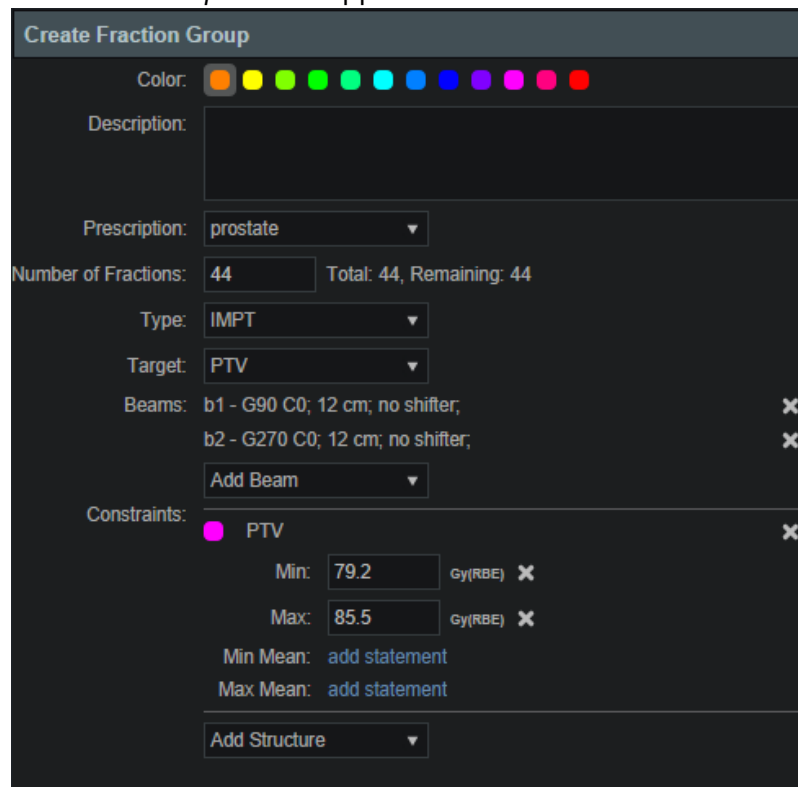After the target constraints have been entered, it's generally good practice to test the plan feasibility. The Feasibility calculation is run by clicking *calculate* at the bottom of this block. The Feasibility calculation is based solely on the constraints and it should be used to ensure there is a possible solution (plan) that can meet the specified constraints. Establishing Feasibility is often an iterative process in order to get appropriate constraints established for a particular plan. In other words, the user may need to enter a constraint, check the feasibility, then progressively tighten the constraint and check the

feasibility until the plan is no longer feasible. It is recommended practice to start by obtaining a feasible plan utilizing only target constraints (and a global max constraint) then add OAR constraints as desired. Remember, using a narrow range of constraints can improve the optimizer performance and improve the resolution of the Pareto surface navigation.

1. Run the *Feasibility* by clicking the *calculate* link

Feasibility
not calculated
calculate
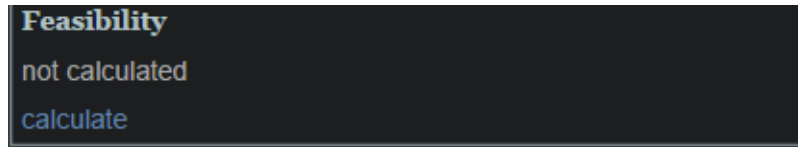
   1. The feasibility should return as passing, if not, please confirm your plan parameters match those shown throughout this walkthrough and try again
2. Now with the target constraints set, we'll continue to add our OAR's
   1. Again these will be set per department protocol
   2. For this example create the following OAR constraints:
      1. Rectum max mean 50 Gy
      2. Bladder max mean 60 Gy

▼ **Constraints / Feasibility**

● skin (Skin)   ✖
      Max: 85.5   Gy(RBE) ✖
   Max Mean: add statement

● Rectum   ✖
      Max: add statement
   Max Mean: 50   Gy(RBE) ✖

● Bladder   ✖
      Max: add statement
   Max Mean: 60   Gy(RBE) ✖

Add Structure   ▼

                                                    OK   Cancel
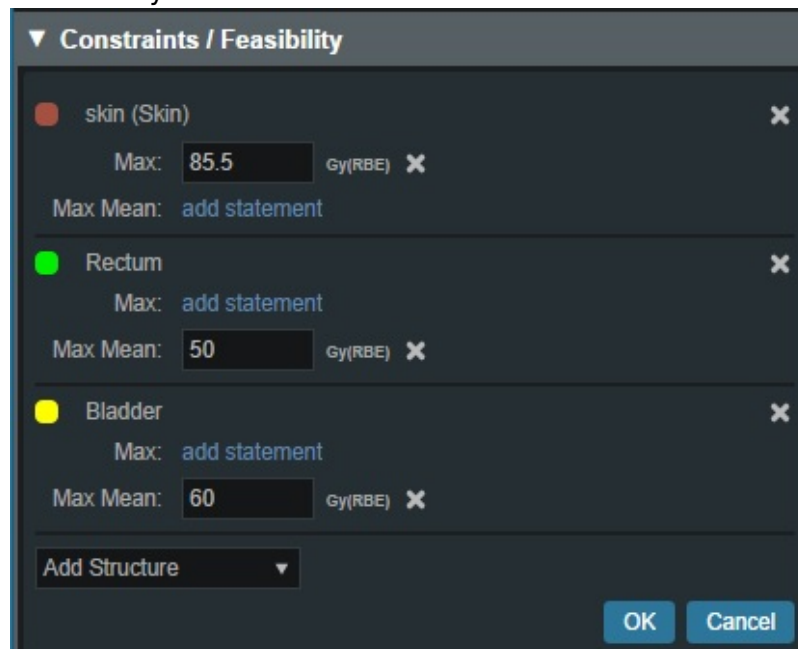
3. Run *Feasibility* as before
   1. The feasibility should return as passing again, if not, please confirm your plan parameters match those shown throughout this walkthrough and try again
4. If the feasibility has passed click the *OK* button

Objectives and Optimizer

1. With narrow constraints set and feasibility established, we will now turn our attention to *Objectives*
   1. *Objectives* are the goals that you would like to achieve and these will be the driving forces

for the *Optimizer*

2. Expand the *Objectives / Optimizer* sub-block and then click *Edit* under the *Objectives* section
3. For this example we will use the following objectives (Click the *Add structure* drop down menu to add the following)
    1. The External_Body (Skin) will automatically populate
    2. Rectum min_mean (Minimize the mean dose to the Rectum)
    3. Testes min_max (Minimize the maximum dose to the Testes)
    4. Left & Right Femur min_overdose 45 Gy (Minimize the amount of the structure the receives dose above 45 Gy)
    5. PTV min_max (Minimize the maximum dose within the PTV)
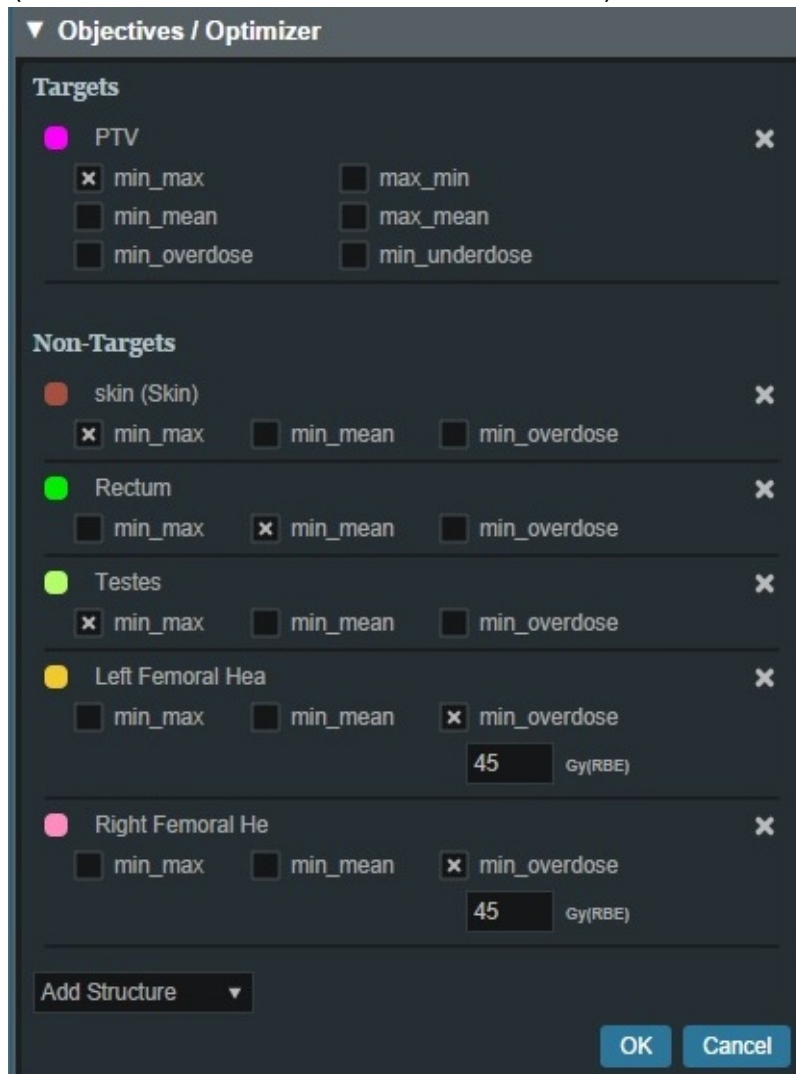
2. Click *OK* to complete the *Objectives*
3. We are now ready to run the MCO, by clicking the *calculate* link
    1. This may take up to 10 minutes for this plan depending upon your available cloud services resources
    2. Keep in mind that even though this process may take some time, the planner will be able to make adjustments easily in the Navigation without running a new plan

Navigation

1. Once the MCO has been completed, you can adjust the relative importance of the objectives using the slider bars in the *Navigation* block by clicking the *Edit* button in the *Navigation* block(see Astroid Optimization *Navigating the Solutions* for a detailed explanation of using the slider bars)
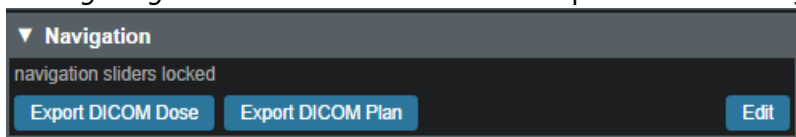
   1. Adjust the slider bars in the *Navigation* block to find what you feel is the optimal plan for this case
      1. Note: All of these adjustments are made without having to run a new plan
   2. If you find a plan that you like, but wish to continue exploring further, you can click the *Save* button to save the current slider state and then continue exploring
   3. You may return to the last saved state at any time by clicking the *Reset* button
   4. The *Cancel* button will close the navigation block, reverting back to the last *Saved* state

2. The plan is ready for physician review at this point
   1. Physicians often find it useful to Navigate the solution and explore trade-offs in real time, which can often alter the traditional physician approval process into an interactive, real-time trade-off analysis and on the spot plan approval
3. After the physician has decided on a treatment plan the user may then proceed to export the chosen plan to the EMR
   1. Note that these standard (non-plan specific) features are covered in other guides and not repeated herein

2016/08/29 16:28

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Last update: **2018/08/16 19:26**

Planning App ResultsAPI

The ResultsAPI is provided to facilitate a controlled and consistent means for accessing necessary treatment plan details and information. The ResultsAPI is most frequently used by customers wishing to develop custom treatment plan reports for clinical patients. From the ResultsAPI treatment plan data can be accessed, including (but not limited to): patient geometries, prescriptions, beam information, spot placements, and plan dose results. It should be pointed out that when users generate custom plan reports they must include an indication of the coordinate system in which any position information is being displayed and users should be reminded that all ResultsAPI position data is provided in either DICOM Patient or IEC 61217 Beam coordinate systems, as appropriate, at this time. Plan reports must also include a list of any density reassignments that were used in the plan.

Most Planning ResultsAPI functions must be called using Thinknode meta requests. Because of this added complexity, an example function call is provided to aid in end user understanding of proper usage.

The Astroid ResultsAPI and META Requests

A fundamental principle of the Thinknode data environment in which Astroid lives is that Astroid stores INPUT data only, not calculation results. As such, this makes it difficult for end users to directly access the "usual" data from a treatment plan. The astroid ResultsAPI was created to address this difficulty by allowing users to access typical data (e.g.: dose, structure geometry, beam geometry, etc) from a treatment plan without knowing how to explicitly construct the complicated requests needed to generate that data.

Most ResultsAPI functions require a treatment plan as an input and return a form of a *calculation_request* object. This object is typically not directly useful to end users, instead, this object is used to generate the request for the final useful data. This calculation request object could be retrieved from Thinknode ISS, parsed, and then submitted as the body of a new Thinknode calculation request. This is slow, cumbersome, and sometimes impossible, as Thinknode imposes a 5MB limit on the size of the request body. Thinknode META requests can be used to circumvent these difficulties and automatically handle the submission of the resulting calculation request object. The necessary details of the META request submission process are described below.

A META request consists of a function that is flagged as a *Generator* function. The Generator function is a normal Thinknode provider function in all regards. However, the return type MUST be a valid Thinknode calculation request. All Astroid ResultsAPI functions can thus be used as Generators in META calculations. When a calculation request is flagged as a META type and submitted to Thinknode, the Generator function will first be processed, which will produce a new calculation object. This new calculation is automatically submitted and its output assigned back to the original META submission, such that the calculation result returned by the META will directly contain the expected (useful) data that the end user requested from the treatment plan.

In summary, the process flow of using the ResultsAPI is as follows:

1. User calls a ResultsAPI function with a specific treatment plan

2. ResultsAPI returns a calculation request for the final data the user requires
3. A META request is submitted with the returned ResultsAPI calculation request (this can be done by reference ID such that the calculation result does not need to be retrieved)
4. The META request result is the useful data that the user requires

ResultsAPI Functions and Version Compatibility

For a comprehensive list of available Planning Results API functions, please refer to the Results API Function List.

The Planning Results API provides two types of functions for generating the request for a treatment plan: Context based ResultsAPI functions and Non-context based ResultsAPI functions. Each type is described more fully below.

Context based ResultsAPI functions

These are the recommended functions to be used when interfacing with the Planning App ResultsAPI, as they will ensure compatibility with past and future versions of the ResultsAPI.

Context based ResultsAPI functions are signified by names prefixed with "api_" (e.g.: *api_generate_plan_summary_request*). These functions check the Thinknode Planning App version context that was used to publish (approve) or last edit the treatment plan and attempt to return a calculation_request for the Planning App version context that was captured in the treatment plan. Since these functions check for the proper context within the provided treatment plan, it's safe to call these functions using any Planning App version that is newer than that of the treatment plan being used as input.

Input Parameters

These functions require input parameters, such as the treatment_plan, as a Thinknode dynamic type. This allows the input data to ignore Thinknode data upgrades when calling the ResultsAPI function for values that can be dependent on upgrades.

Return Data

The context based ResultsAPI functions return a *context_based_calculation_request* that contains the Thinknode Planning App context ID used for the plan and an optional calculation_request that should be submitted using the returned context ID.

These functions use the following logic to attempt to generate a compatible *calculation_request* for the Thinknode Planning App version context ID captured in the treatment plan. This request is created by the following logic:

- If the ResultsAPI function does not exist for the captured Planning App version, the optional<calculation_request> will be returned as null
- If the ResultsAPI function signature has changed, the calculation request will be constructed for the Planning ResultsAPI version that corresponds for the returned context ID.

Function Usage

These context based ResultsAPI functions return a special type of calculation request object that is not directly usable within a Thinknode META request as they contain the additional context data needed to ensure the desired calculation is performed with the appropriate Astroid Planning App version. The process of running a context based ResultsAPI request consists of the following steps:

- Submit the initial "api_*" function request as a normal (non-META) calculation using the current Planning App context
- Retrieve the result of the above calculation and get the context ID
- Perform a META request using the above context, setting the META Generator as the request portion of the above "api_*" function result (if it's not null)

Non-context based ResultsAPI functions

These functions are not recommended to be called directly unless the caller specifically wishes to recompute the resulting data with a new Astroid version. These functions construct a request for the end data while not taking into account the captured Planning App context ID of the treatment plan, therefore data upgrades and other changes may be applied to the inputs and outputs, such that the returned data may not exactly match that of the original treatment plan at the time of approval (publishing).

Non-context based ResultsAPI function names are not prefixed with "api_" (e.g.: *generate_plan_summary_request*).

Example

In the .decimal astroid-script-library there is a script called *planning_results_api_example.py* that provides a basic example of calling and accessing the ResultsAPI using META functions.

In this particular example the *api_generate_plan_summary_request* is the ResultsAPI function being called using the current Planning App context installed in the target Thinknode realm. The returned value contains the context ID of the Thinknode Planning App version which created the treatment_plan and the appropriate calculation request for that Planning App version for generating the *plan_summary*. The generator function and META request is submitted using the returned Planning App context ID from the ResultsAPI function. The result of the META request returns the extracted data to use in generating treatment plan reports.

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Last update: **2018/08/21 20:55**