



The Planning Software Behind the Bright Spots on Ceres: The Challenges and Successes of SOA

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Agenda

1. History of the Science Opportunity Analyzer
2. Development Challenges
3. Preliminary Changes
4. Enhancements
5. Future Work

Impetus

Observation: A sequence of remote sensing actions a certain instrument takes to achieve a specific science goal.

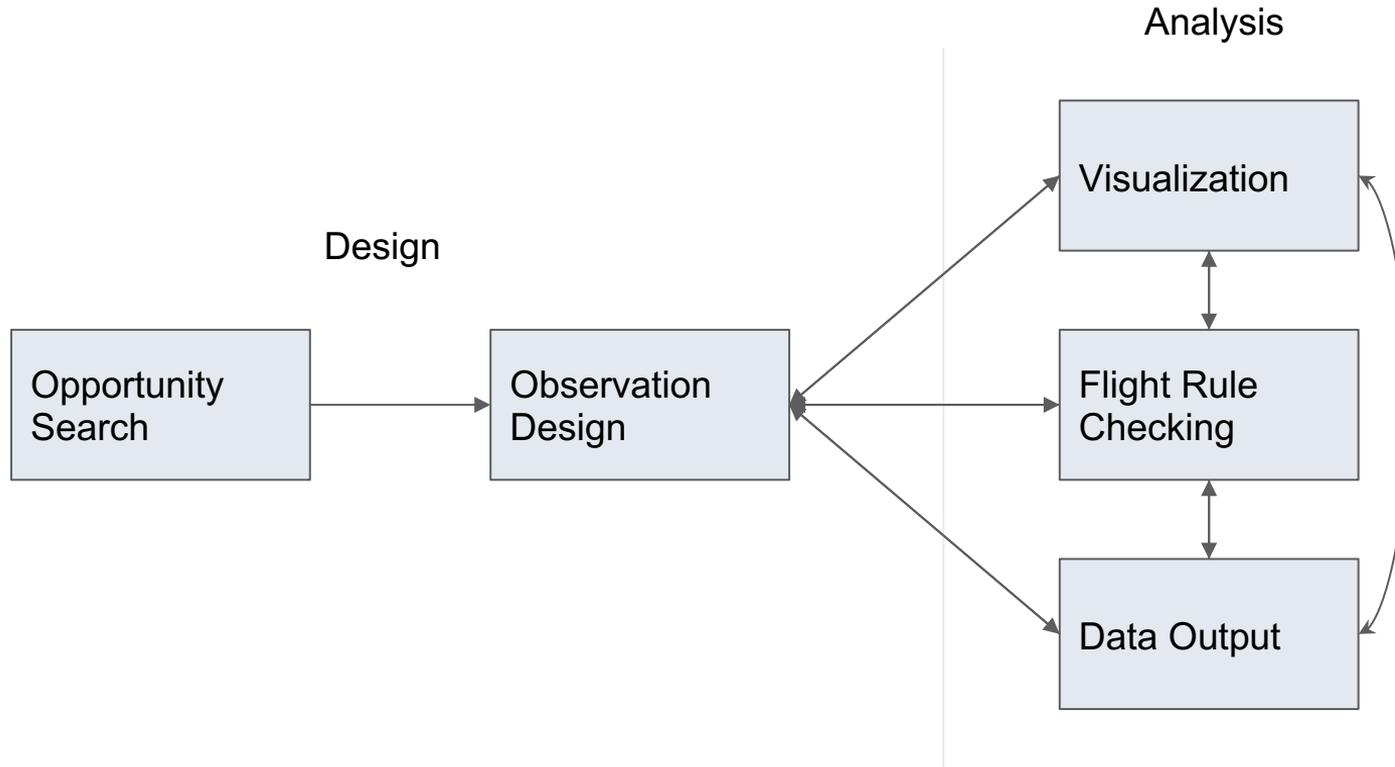
Circa 1998, the observation design process was convoluted and fragmented. A Quality Function Deployment (QFD) was initiated to define an improved software for Cassini.

From the QFD, the software needed to fulfill the following use cases:

- Opportunity Search
- Observation Design
- Visualization
- Flight Rule Checking
- Data Output

The software also had to be multi-mission and ingest SPICE data.

Use Cases



Opportunity Search

Input: Geometric conditions

Output: Time intervals

▼ Search Criteria

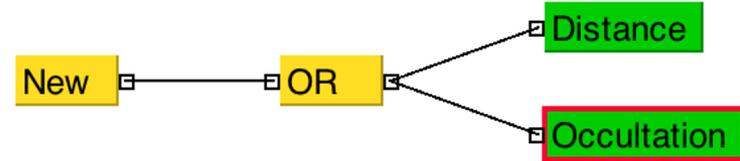
▼ Logical Condition

- AND
- NOT
- OR

▼ Trajectory Related

- Angular Rate
- Apparent Diameter
- Central Meridian
- Distance
- Eclipse
- Elongation
- Occultation
- Orbital Longitude
- Phase
- Quadrature
- Range Rate
- Separation
- Transit

Example: When are these Occultation and Distance conditions true?



Occultation constraint:

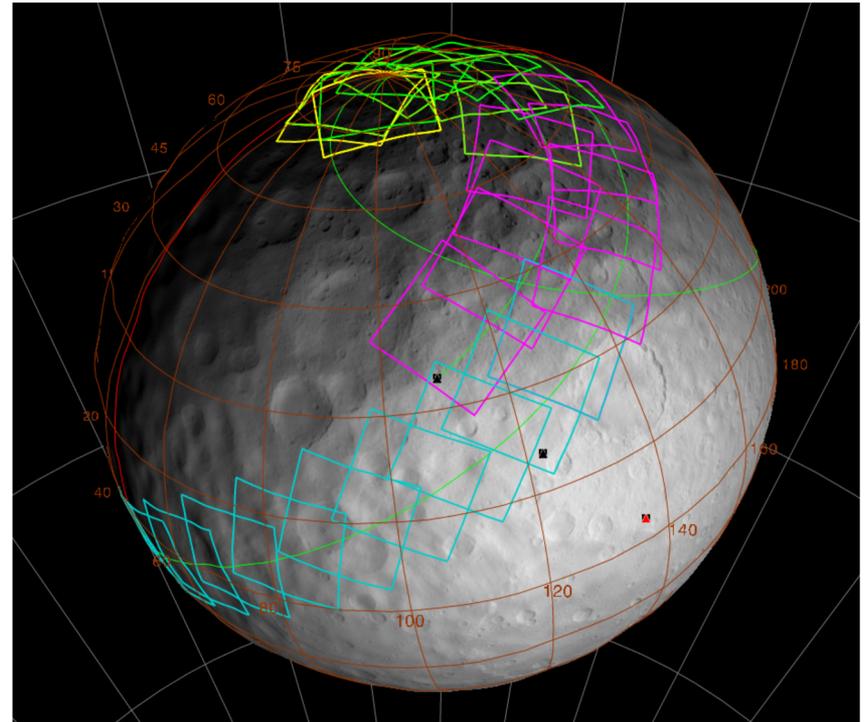
- Begin time: t1
- End time: t2
- Occulted body: Sun
- Occulting body: Ceres
- Observer: Dawn

Distance constraint:

- Begin time: t1
- End time: t2
- To body: Ceres
- From body: Dawn
- Test type: <
- Value: 1000000 km

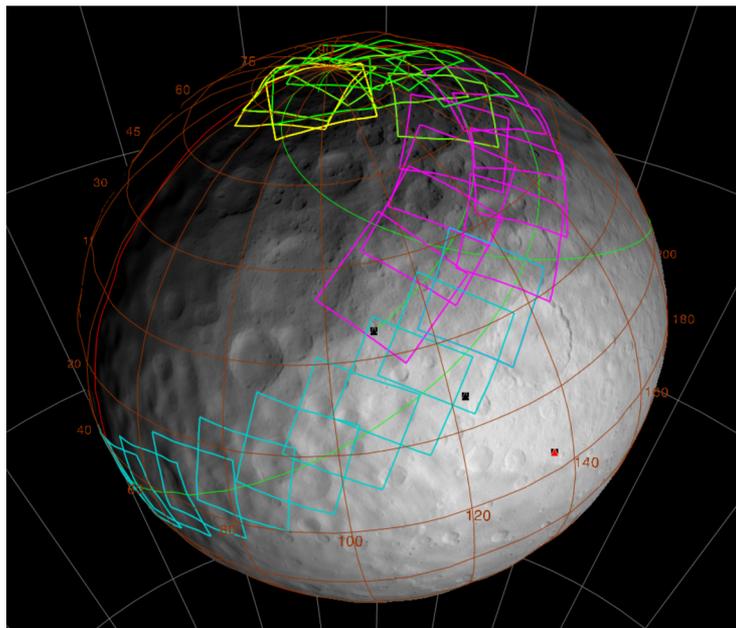
Observation Design

- **Input:** Time intervals
- **Output:** Observation
- Observations have activities. Activities result in footprints.
- Observations are designed at the activity level
- Activity (Track activity):
 - Start time (can be relative)
 - End time
 - Instrument
 - Pointing (vectors, targets)
 - Frequency
 - etc.

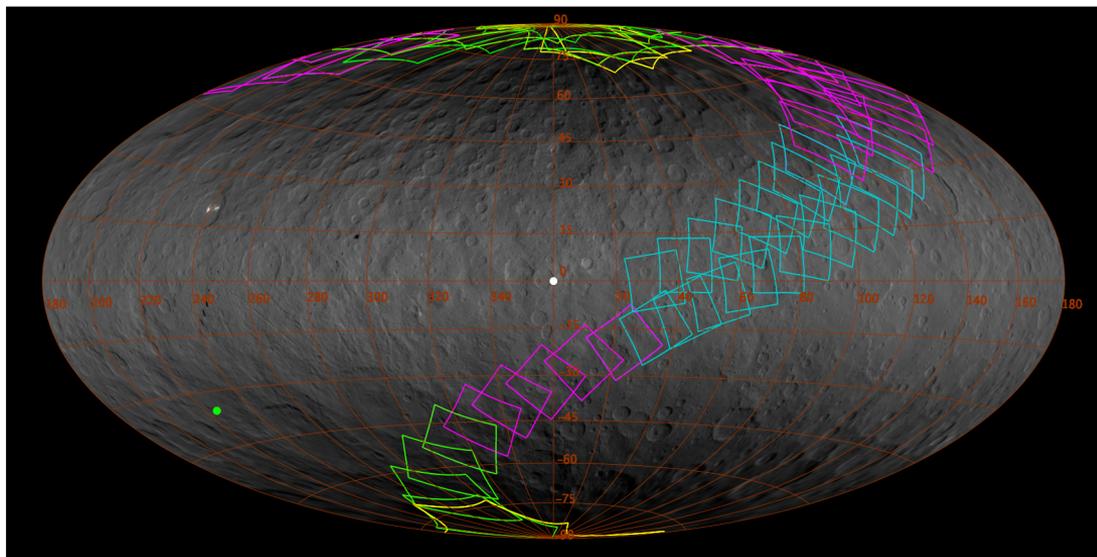


Visualization

3D

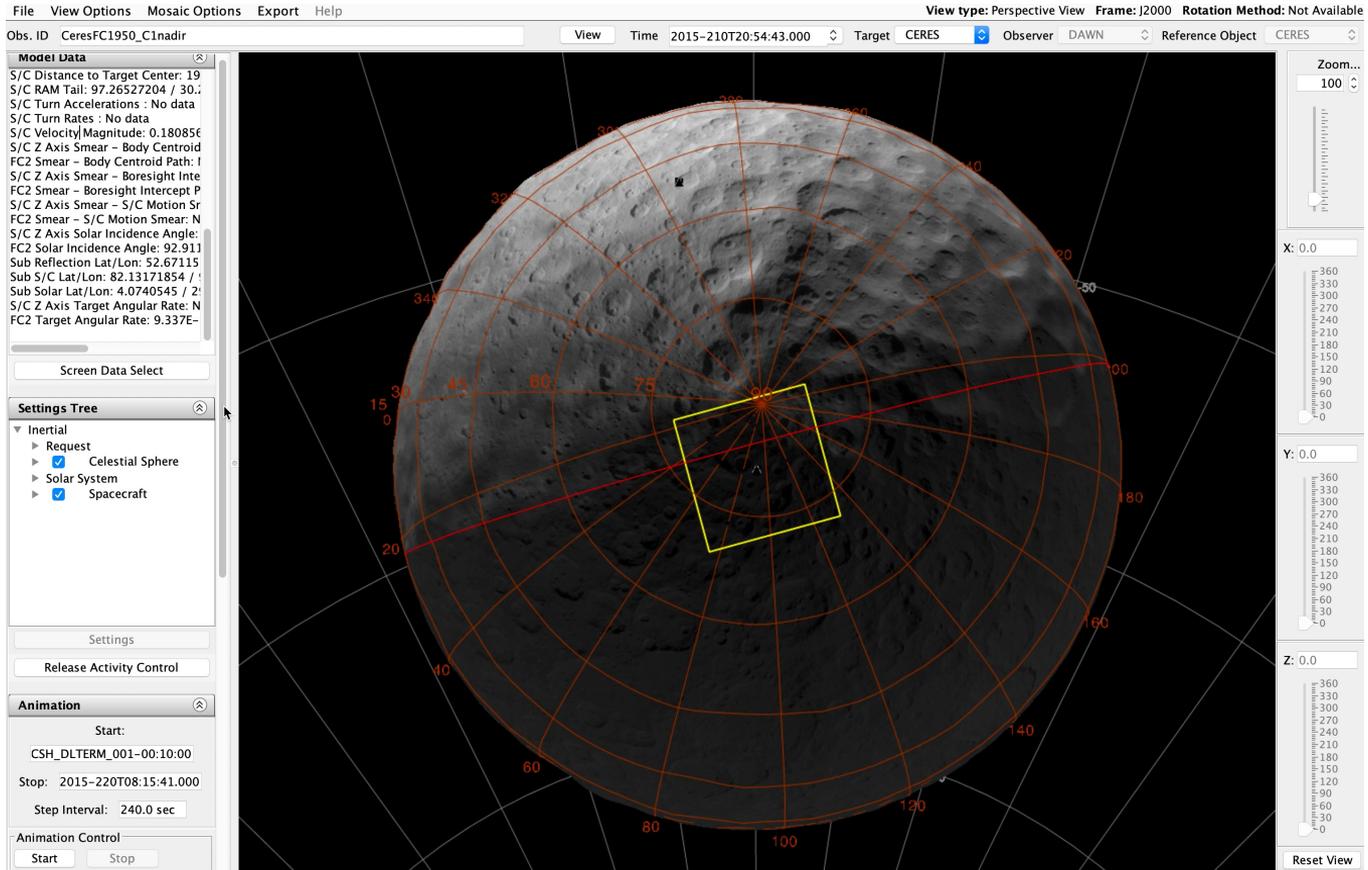


2D (Mollweide)



Other types of visualization: Skymap and Cosmographia.

Visualization



Flight Rule Checking

Input: Geometric conditions

Output: Time intervals/Visualization

Example: FC Boresight Sun
keep-out zone for image
collection

If FC1 and FC2 are pointed
within 0-20 deg of Sun, **flight
rule violation!**



Flight Rule Builder

File Export

New Or Angle Angle

Constraints

- Logical Condition
 - AND
 - OR
- Activity Duration
 - Activity Duration
- Distance
 - Distance
- ExclusionZone
 - Anale
 - Anale + ASD
 - Anale + ASD + Distance
 - Anale + Distance
 - Star + FOV

Copy Paste Cut Delete All Write to list New

Angle parameters

Name	Value	Default	Range	Com...
Rule Type	Violation	Violation	Violation,Warning,Information	
Instrument/Axis	FC1	S/C X Axis	S/C X Axis,S/C -X Axis,S/C Y Axis,S/C ...	
avoidedBody...	SUN	SUN	SUN,MOON,EARTH,MERCURY,VENUS,M...	
Log Message	During FC1 image d...	ExclusionZone viol...		
minAngle	0 degrees	0 degrees	0 - 360	
maxAngle	20 degrees	360 degrees	0-360	
exposureLimit	0 sec	0.0 sec	0.0	

Click tree branch indicator to view events available in the category of interest.
Events can be selected and inserted into the query by clicking an event and dragging it to the Events Window

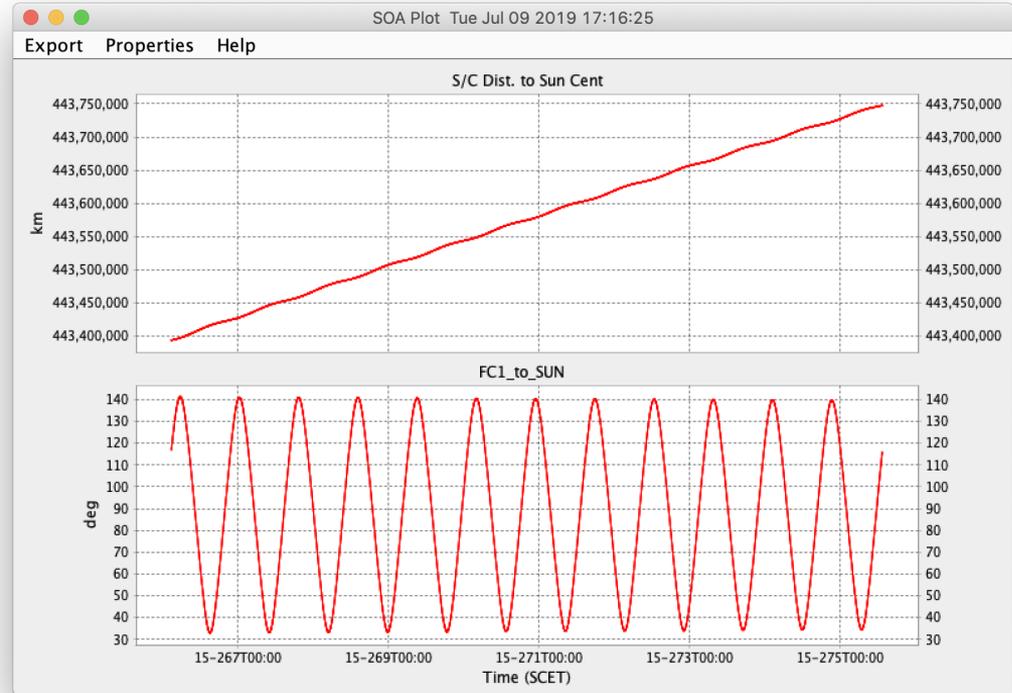
Data Output

Data can be output for a variety of values:

- Angles
- Velocity
- Resolution
- Distance
- Turn rate
- Lat/Lon, etc.

Input: Observation or Trajectory

Output: Plot or Tabular Data



SOA's Development Challenges



- **Cyclical Funding**
 - Not maintained by multi-mission software development organization. Funding comes and goes with projects.
 - **Solution:** Collaboration between line management and project. Support from multi-mission software org.
- **Staffing**
 - Very specific set of skills needed: spacecraft and instrument geometry, software architecture, software development, and computer graphics. Over-reliance on one to two developers.
 - **Solution:** Collaboration between line management and project. Distribution of knowledge.
- **Getting the Right Requirements**
 - Users are scientists, developers are engineers. They might have diverging ideas for the software.
 - **Solution:** Improved process.
- **New Capabilities vs. Architectural Maintenance**
 - Users want new capabilities, and developers must not take shortcuts. Architectural qualities of software tend to degenerate unless developers consciously care for the architecture.
 - **Solution:** Developer diligence and self-determination.
- **Changing Software Technologies and Processes**
 - Risk, concerns about cost, and a belief that current technology and processes are good enough slow the introduction of new technologies and processes.
 - **Solution:** Developer diligence and self-determination.
- **Adaptability to Other Projects**
 - Project(s) fund SOA, but SOA needs to keep being multi-mission.
 - **Solution:** Developer diligence. Support from multi-mission org.

Preliminary changes

- **Development Team**
 - 2 new specialized developers with geometry, software architecture, software development, and computer graphics background.
- **User/Developer Teamwork**
 - Agile process with fast iteration and customer acceptance.
 - Better communication.
 - Co-location.
- **Development Ergonomics**
 - Standardization or build process.
 - Use of IDE.
- **Performance and Bug Fixes**
 - Human Analysis
 - Static Code Analysis
 - Refactor



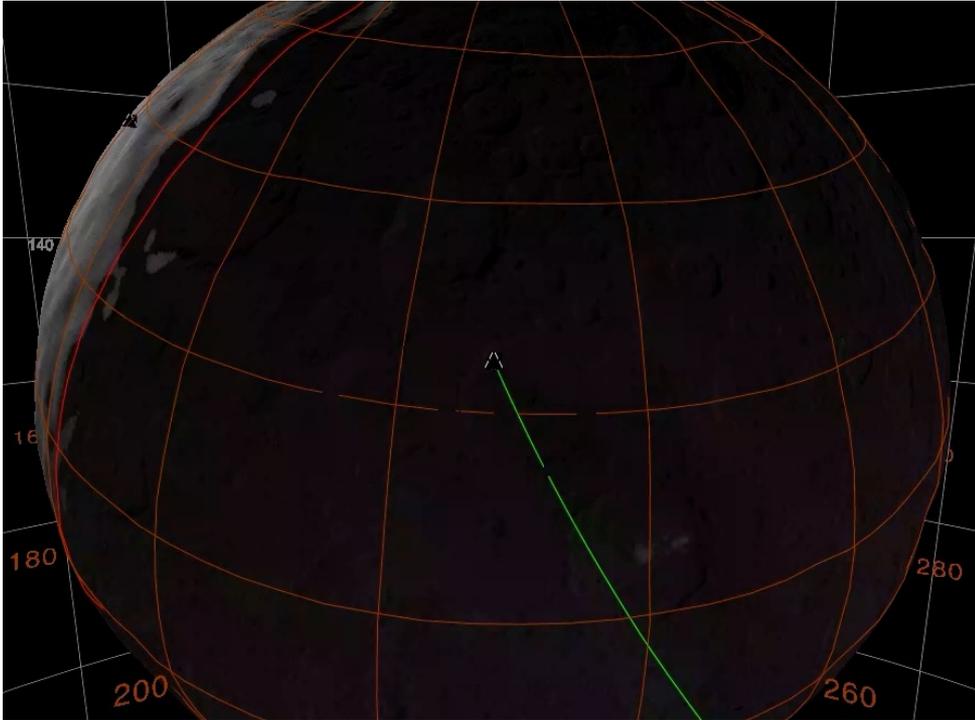
Enhancements

Automated Observation Design

- Goal: improve user efficiency by reducing manual efforts without straining developer resources
- Solution: automate observation design by stepping through time windows where a condition is met, and greedily perform data acquisition
- Result: partial automation
 - User specifies time range and properties
 - Software reports both results and summary statistics
- A task that took days, now accomplished on the order of minutes!

Enhancements

Geometric Track Activity



Track Activity that starts and stops once certain geometric conditions are met

Conditions may be based on:

- Incidence Angle
- Emission Angle
- Phase angle
- Distance
- Boresight longitude
- Boresight latitude

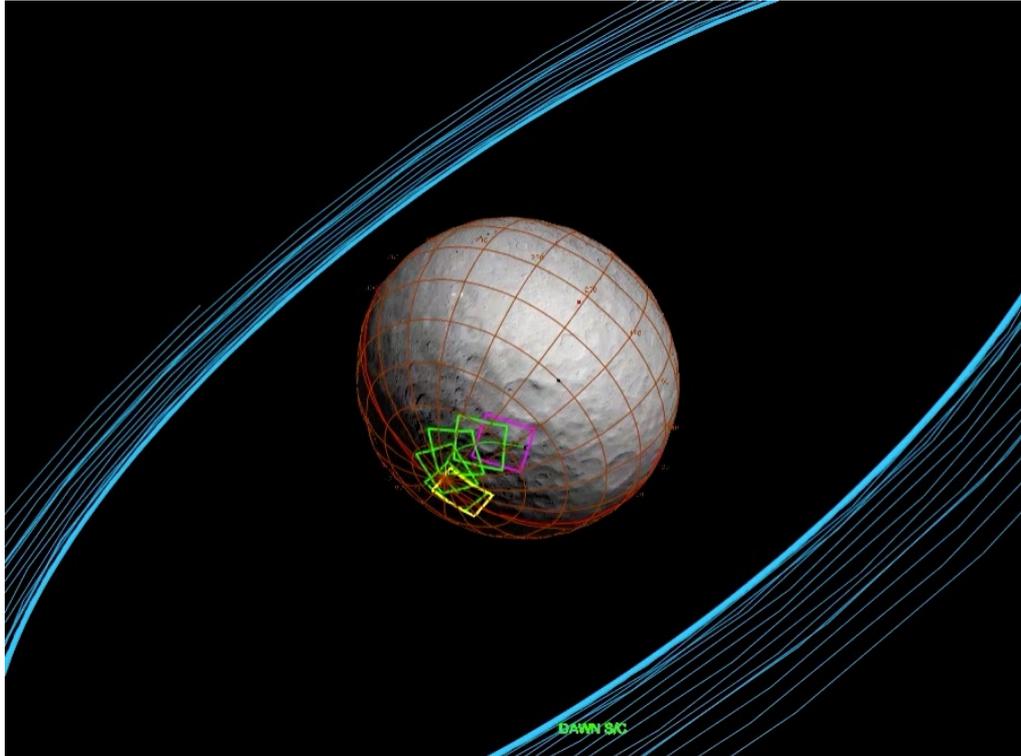
Enhancements

Opportunity Search Modernization

- Original user interface proved difficult for users to adopt
- Interface was upgraded to use an interactive tree
 - Nodes are logical operators, leaves are geometric events
 - GUI became more intuitive to use and understand
 - Tree structure allows complex geometric conditions to be expressed
- Geometric event search engine changed from Percy to SPICE

Enhancements

Movie Creation



Prior to 2016, SOA only exported images

Animations can now be recorded and saved

- Users select start and stop times by toggling the “record” button
- All actions within the visualizer are captured

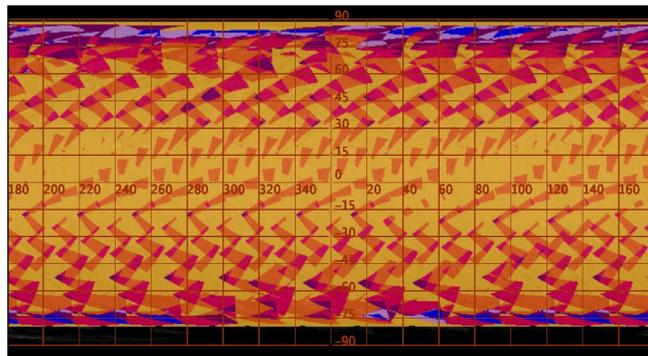
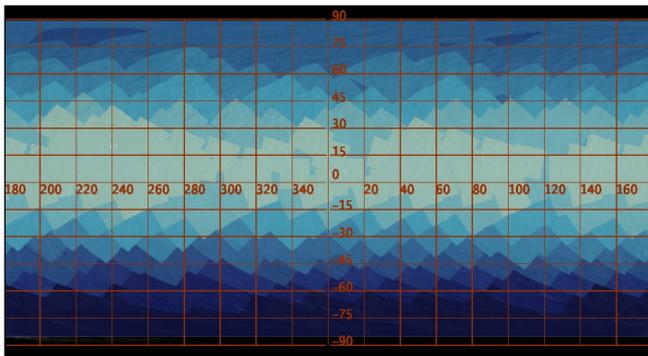
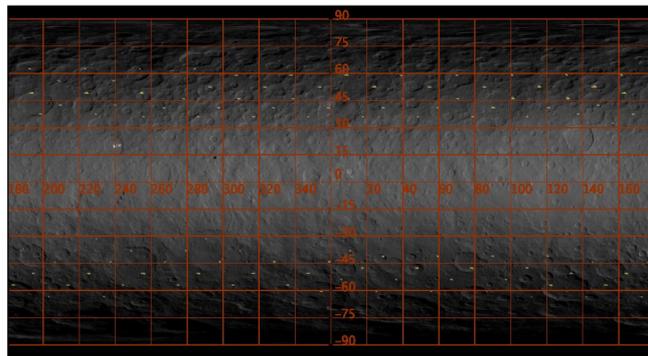
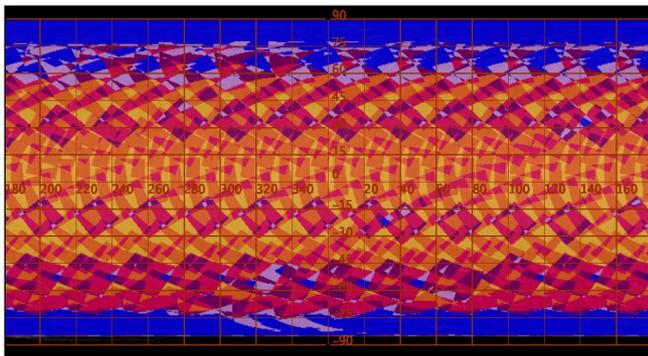
Enhancements

Coverage Analysis

- Coverage and resolution key metrics of orbital observations
- Users would analyze SOA observations using other tools
 - Added extra steps to normal workflow
 - Relies on external, closed-source tools
- As of 2017, both can be computed in the SOA visualizer

Enhancements

Coverage Analysis



Coverage and Footprints

Footprint Data

Calculate coverage

Grid resolution (deg lat/lon):
0.5

Transparency %:
75

Reset Colors

Constraint preset:

- Coverage
- No Screening
- Stereo Optimal
- Stereo Usable
- SPC Optimal
- SPC Usable
- Custom

Max incidence (°): 90

Min emission (°): 0

Max emission (°): 90

Results and color legend

Views	Color	Body %
1	Yellow	99.9
2	Orange	84.7
3	Red	48.3
4	Purple	21.2
5	Light Purple	9.7
6	Blue	5.4

Future Work

- Architectural Enhancements
- Addition of more user-friendly features
- Updates to the Visualization Back-End
- Parallelization of the SPICE Engine
- Documentation and Testing
- Use in the Psyche Mission
- Multi-Mission Funding



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