Advances in Science Planning Tools with

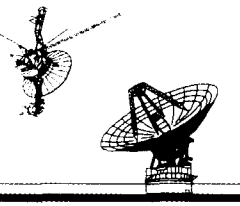
tunity Analyzer (SOA)

Services & Applications

Carol A. Polanskey, Barbara Streiffert, Taifun O'Reilly, and Joshua E. Colwell

Jet Propulsion Laboratory

Pasadena CA



Background

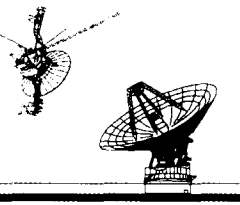
•Scientists on spacecraft instrument teams need the ability to identify and design observations for their instruments.

•They generally do not want or have access to detailed spacecraft commanding software.

•SOA has been developed as a multi-mission science planning tool that allows scientists to design, check, and modify observations and feed those designs into the detailed uplink software system without having to use the entire uplink software system.

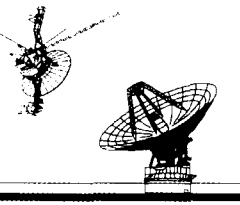
•Initial SOA design used Quality Functional Deployment to survey the user community to incorporate their requirements into the software requirements.

•SOA is java-based, and makes use of the JPL Navigation and Ancillary Information Facility (NAIF) SPICE software toolkit.



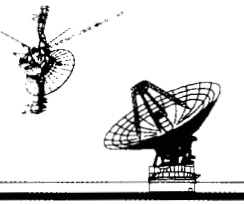
What is SOA?

- **First tool a scientist/mission planner will use.**
  - –Identify key opportunities & check out the feasibility of potential observations.
  - –Easy to use by wide range of non-JPL science team members and support staff.
  - –Run on multiple platforms: SunOS, Windows, Linux.
  - –Based on standard NAIF/SPICE tools providing high fidelity.
- **Revisit observation following changes to the "plan".**
  - –Retrieve new time window or validate observation following updates to the s/c trajectory.
  - –Communicates with other downstream sequence development software to validate observations following integration.



SOA is a Multi-Mission Tool

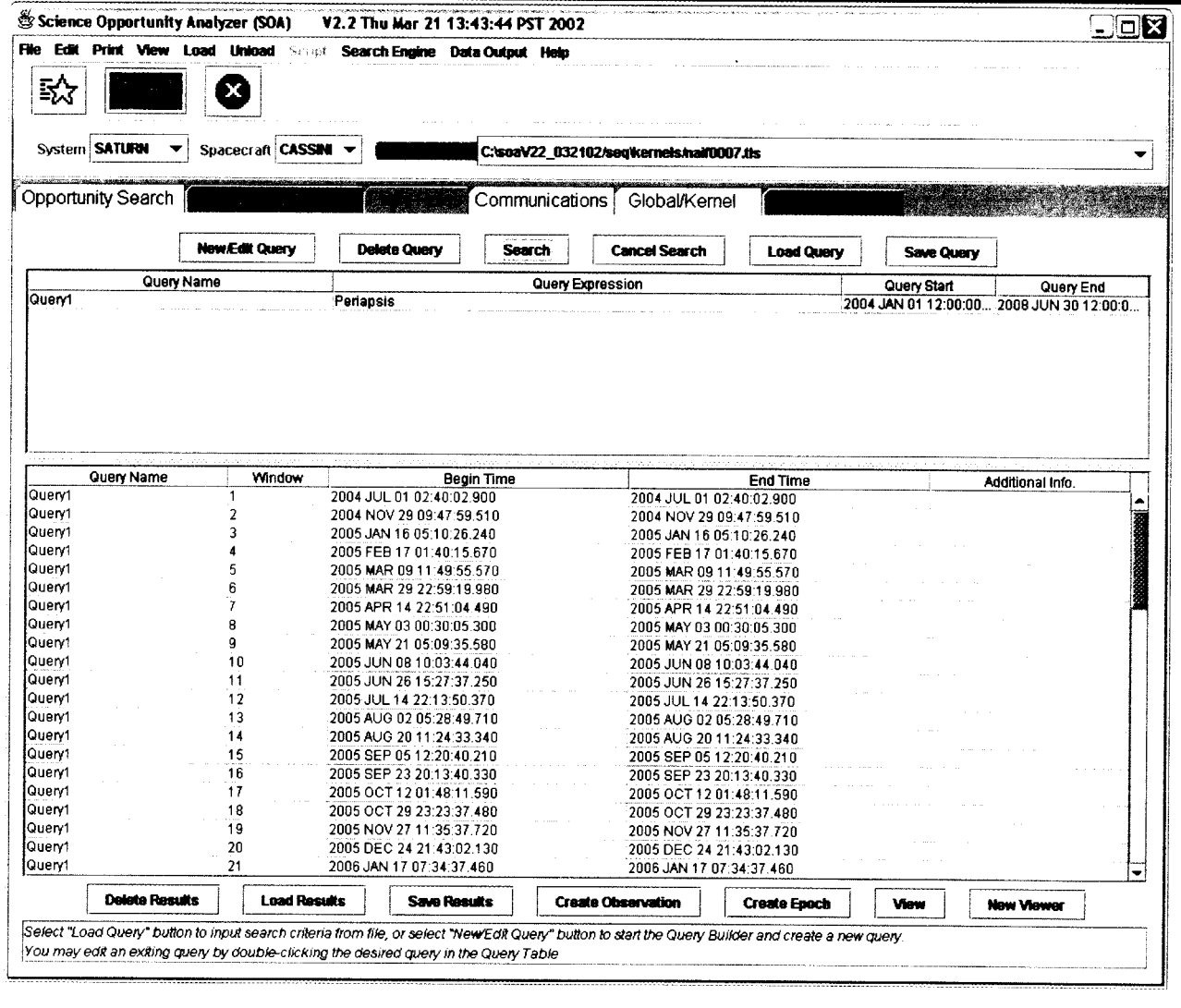
- SOA is configurable to a specific mission.
  - This process is called "adaptation". Adaptation adds the mission specific data for SOA to work with. This mission specific data will include flight rules, observation types, physical phenomena models, celestial body data, instrument data, spacecraft-specific data and a spacecraft trajectory. Much of this data can be provided through the use of JPL navigation files.
- SOA's first customer is the Cassini/Huygens mission to Saturn.
  - Examples in this presentation are for the Cassini mission. Cassini arrives at Saturn July 1, 2004, to begin a four year orbital "tour" of the Saturn system, including planet, rings, satellites, and magnetosphere. SOA is designed to handle observations of each of these diverse targets.

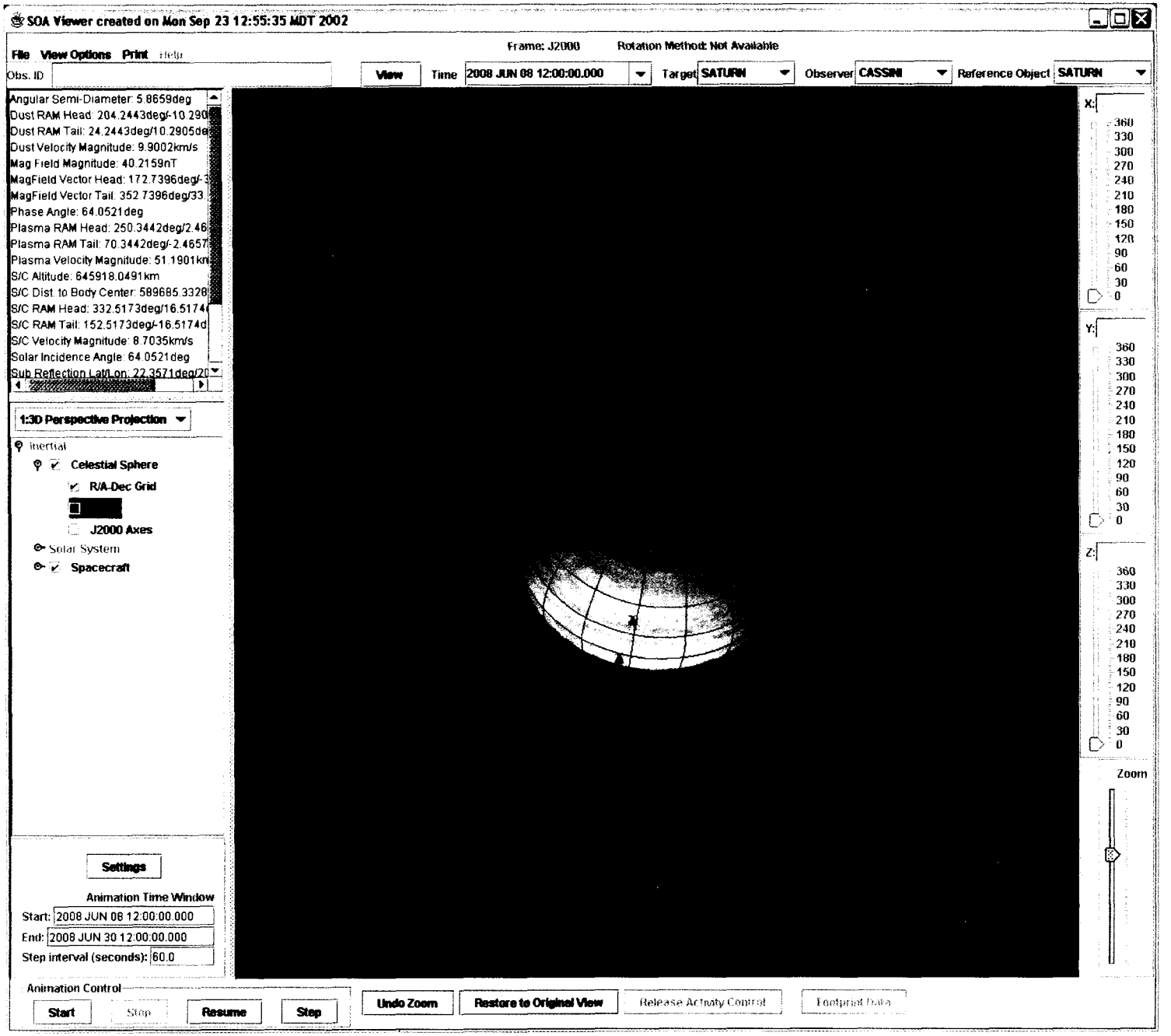


SOA Capabilities

- Visualization
  - Visualize the system in 3D and 2D from the point of view of any object in the system, including the spacecraft, or from an arbitrary point of view.
  - Visualze observations, with projections of instrument fields of view onto any object in the system, including observations designed in other software.
  - Animate the view for arbitrary times or for the period of an observation.
- Opportunity Search
  - Search for a science opportunity, i.e., one or more time "windows" when a science observation can occur (uses Percy and EVENTS search engines)
  - Use visualization to validate observation geometry.

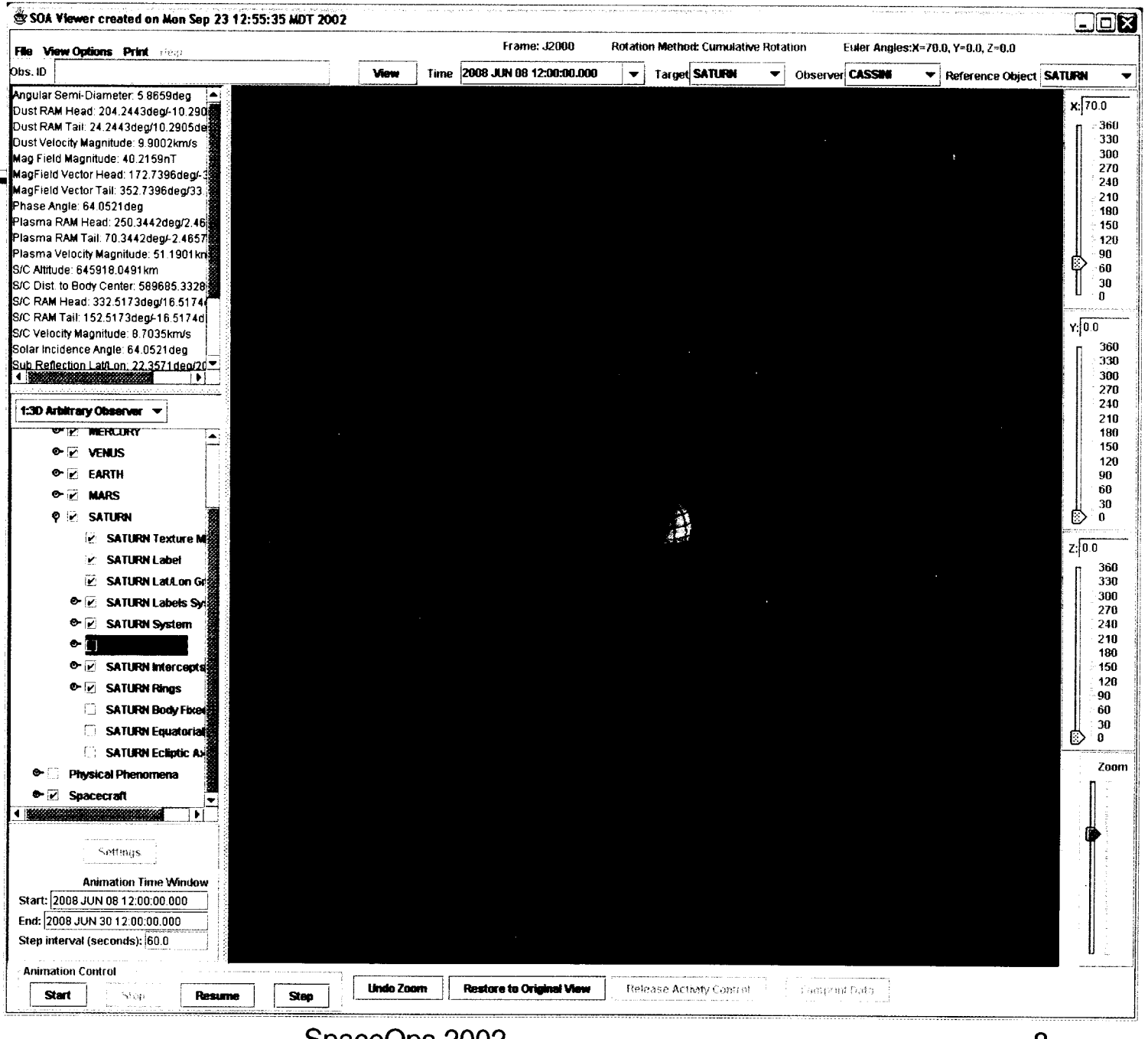
List of times when user-specified geometric criteria are met, returned by one of two opportunity search engines used by SOA: Percy and EVENTS.

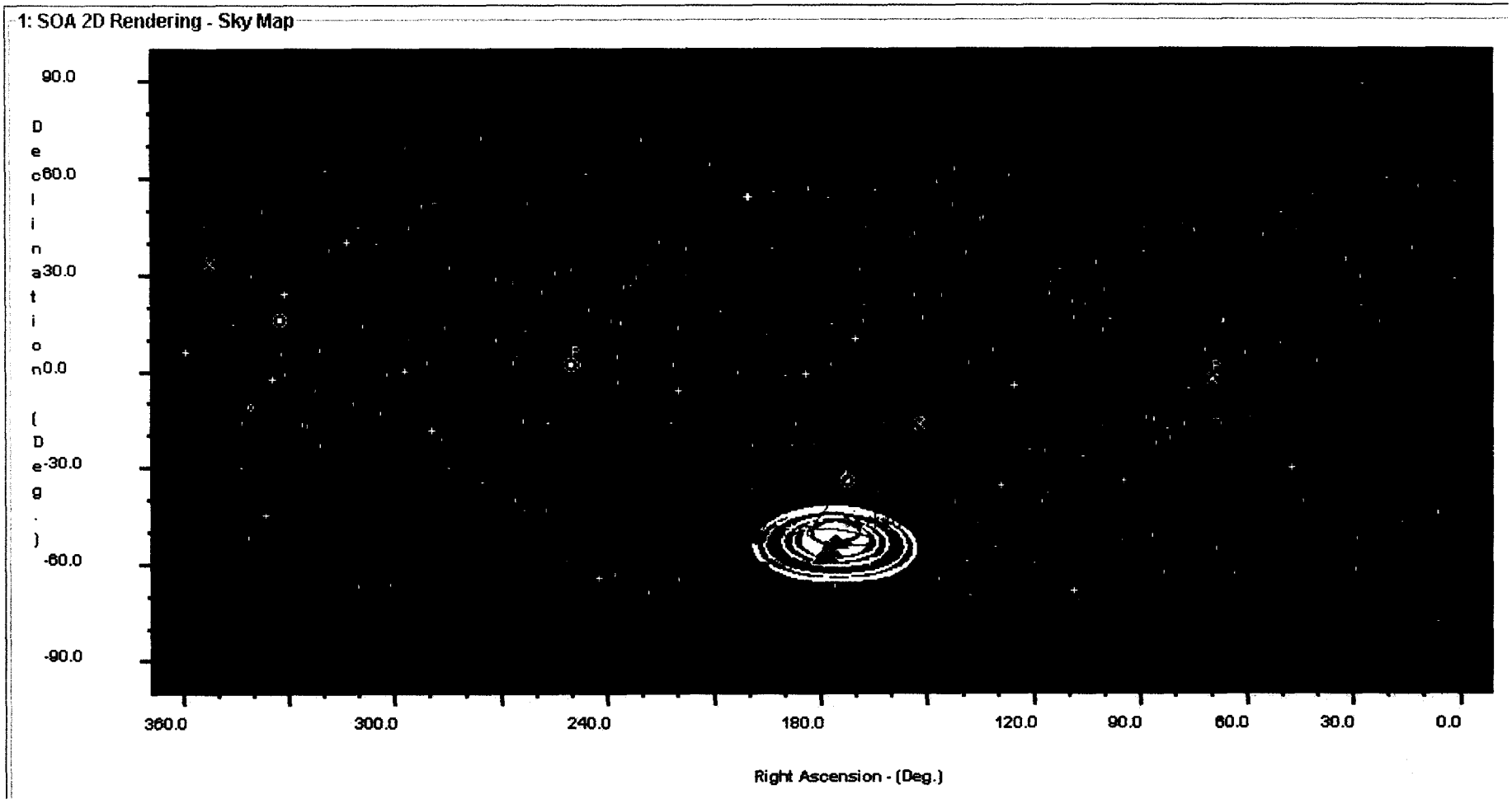




3D Perspective View of Saturn as seen from Cassini, June 2008

3D Perspective View of Saturn as seen from a user specified vantage point, June 2008. The Cassini spacecraft is visible at upper right, along with spacecraft and satellite trajectories.



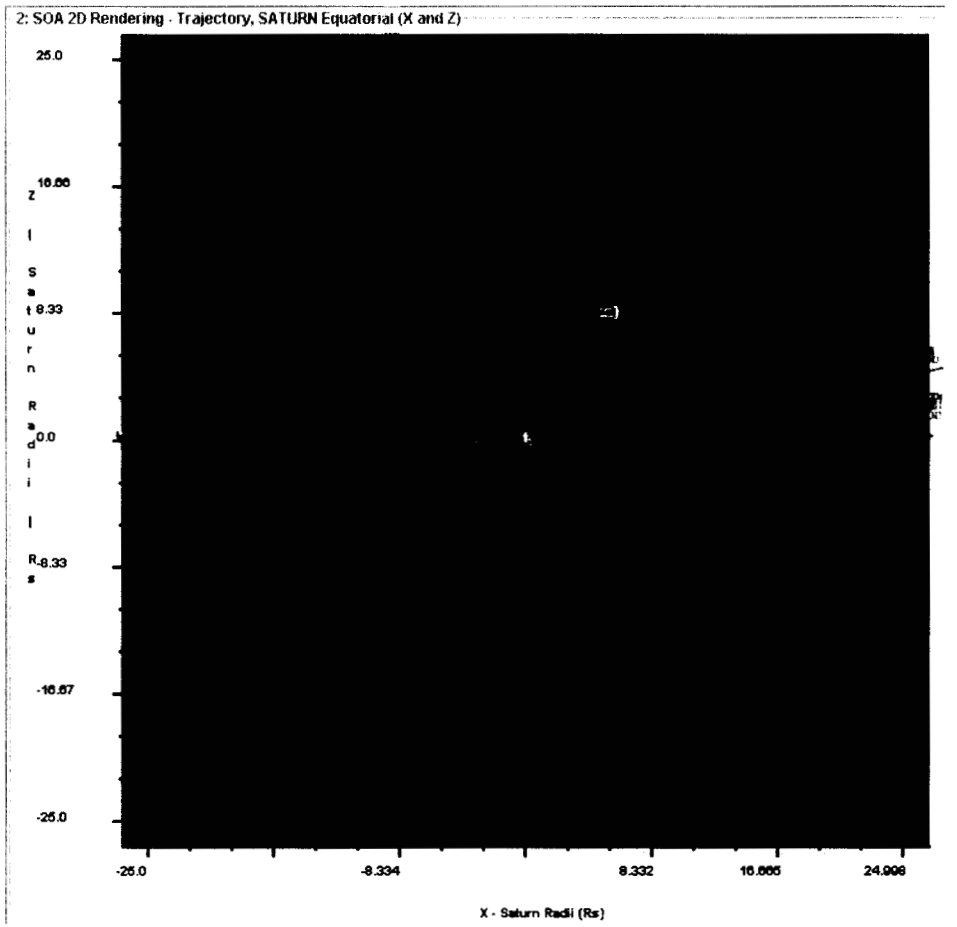


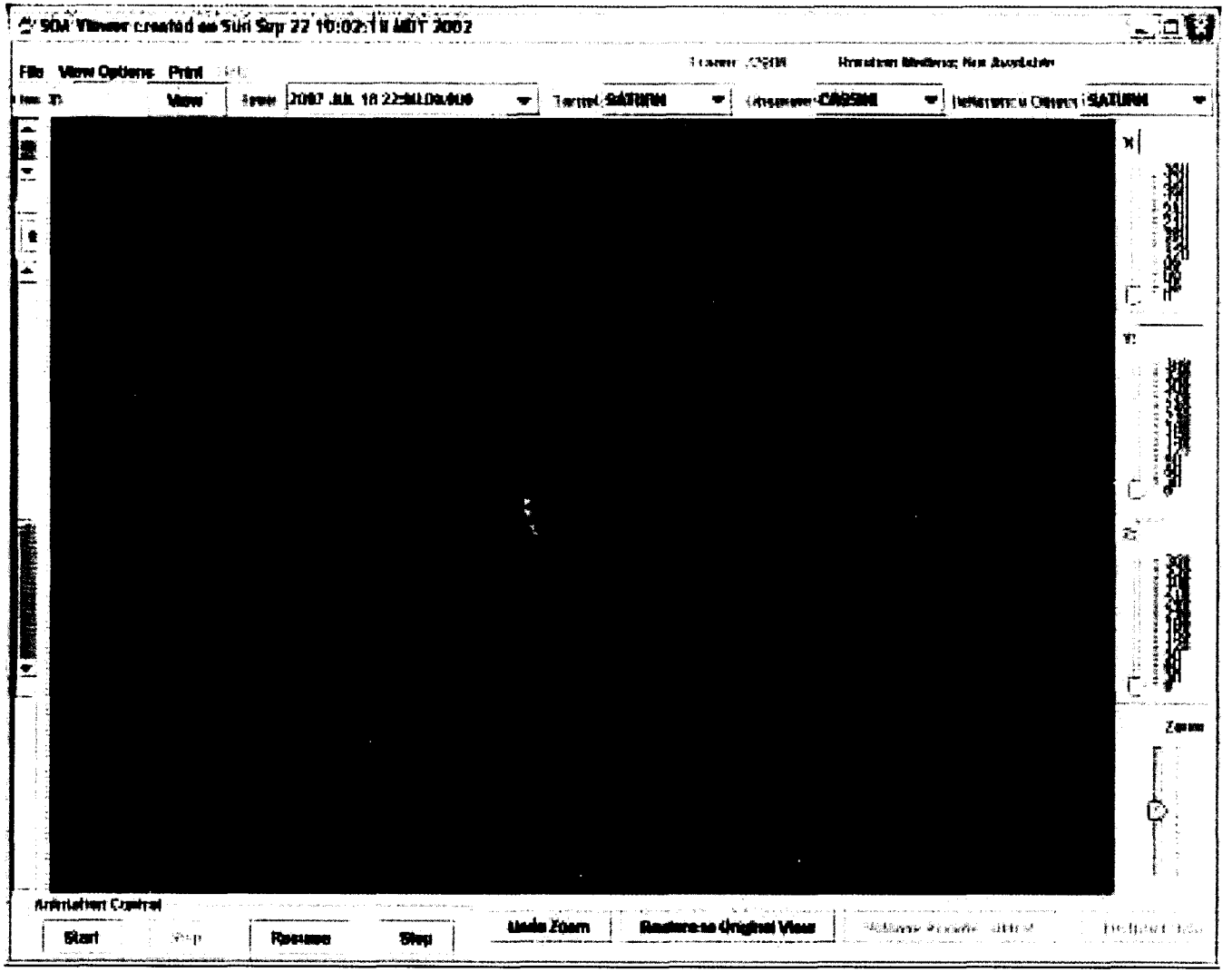
2D Sky Map at the same time, as seen from Cassini.

2D Trajectory View of the X-Z plane, with spacecraft and satellite trajectories shown. Time tick marks help the user identify times of interest for an observation.

Multiple viewers with various view types may be opened at one time.

All views may be animated and manipulated for zoom and rotation.




File
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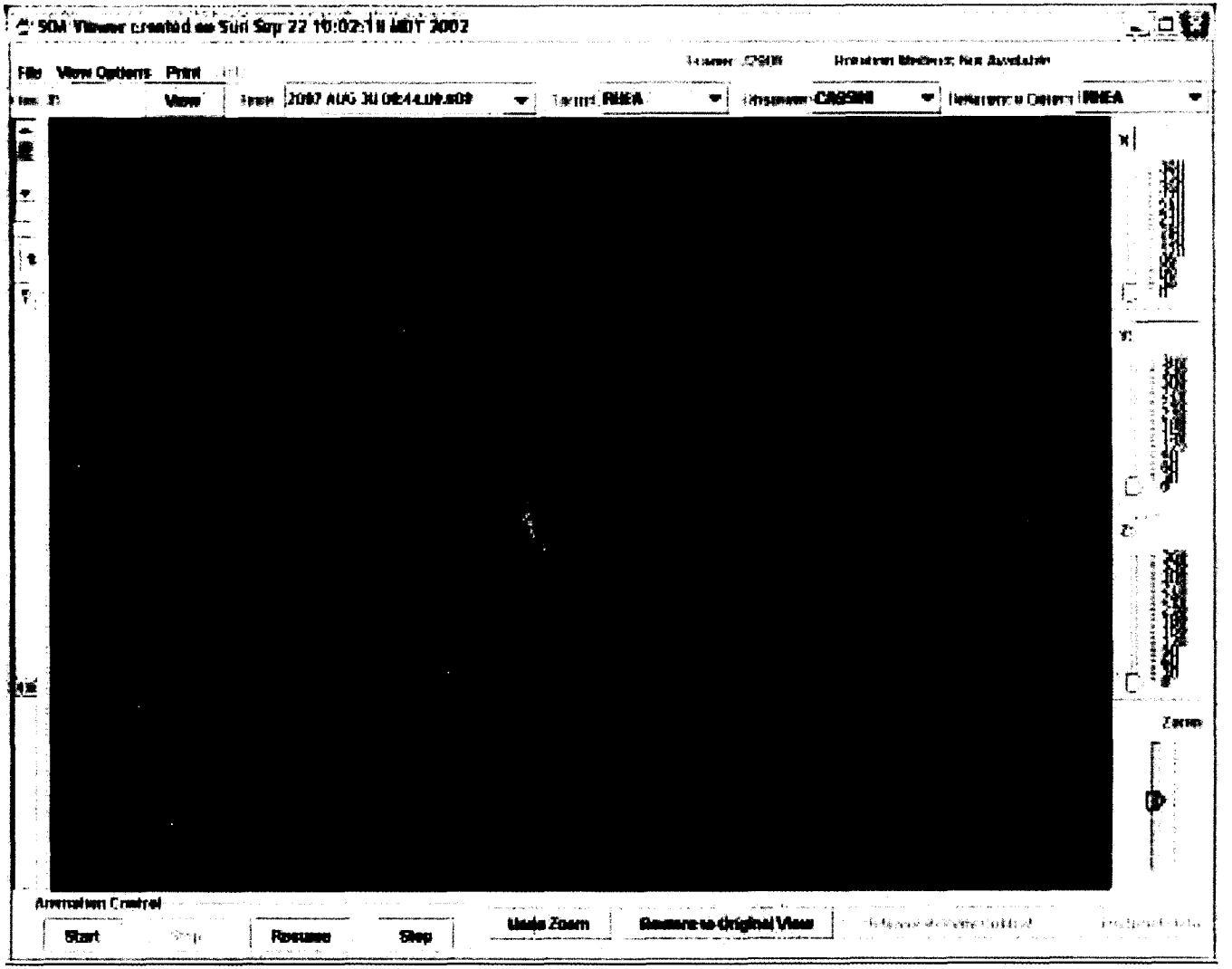
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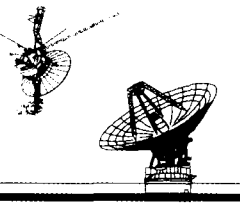
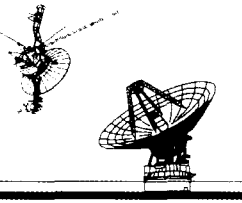


SOA Capabilities (cont.)

- Observation Design
  - Plan & design science observation(s) at the times(s) suggested by the opportunity search.
  - Scientist control and verification of observation parameters to ensure desired observation objectives will be met (exposure times, target coverage, observing geometry).
  - Detailed parameter control with mapping to spacecraft sequence generation software parameters.
  - High level "Scoping" design tool for "what if" studies.
- Constraint Checking
  - Checks high level observation design constraints early in the sequence development process.
  - Provides feedback on violations.
  - Permits user-level and project-level rule checking.



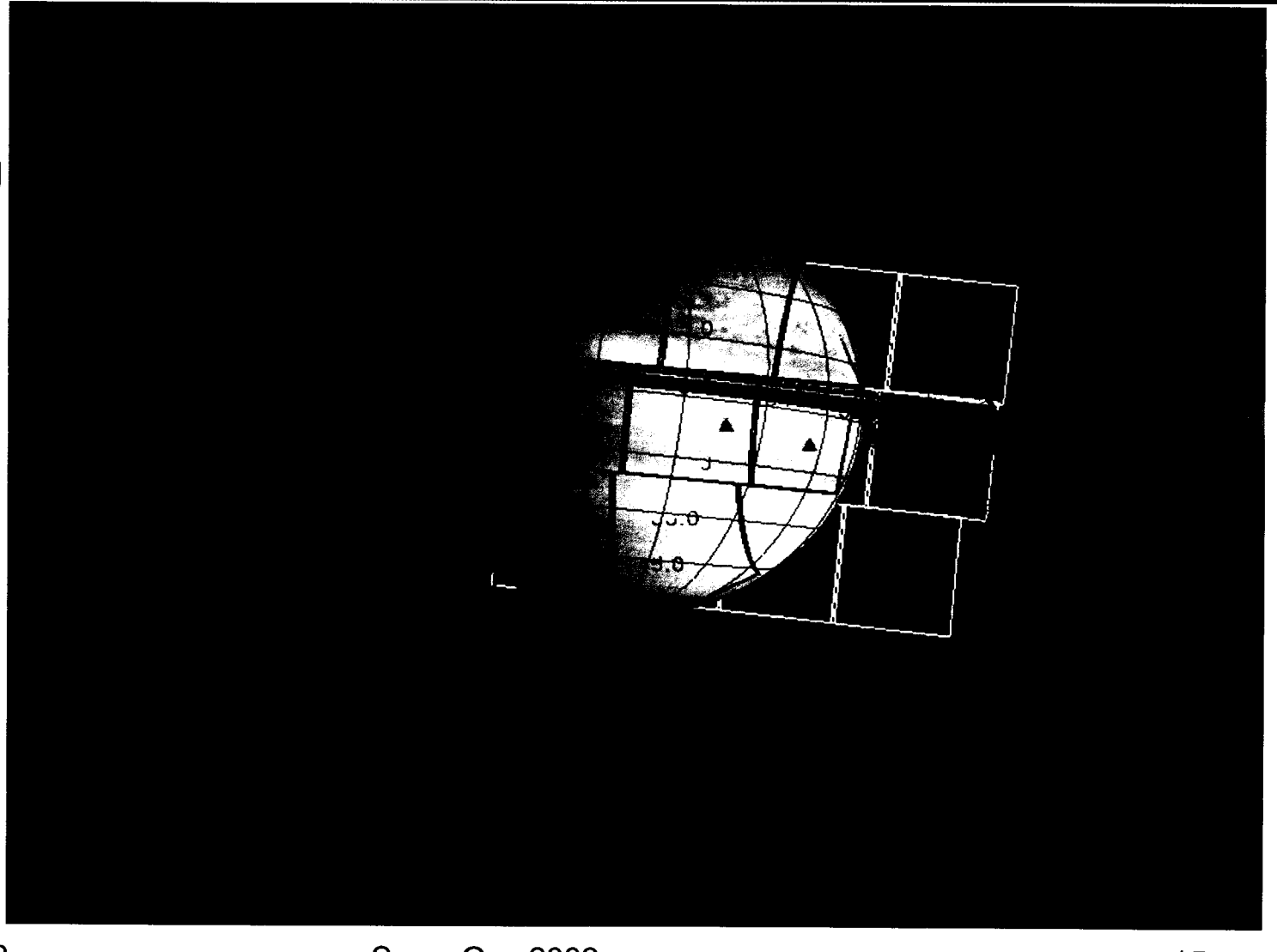
New Obs | Convert Obs | Apply | Write to list | Module Parameters | Nominal Twist | Check Constraint | 00 violations | View | New Viewer

New Observation:START_STOP_MOS

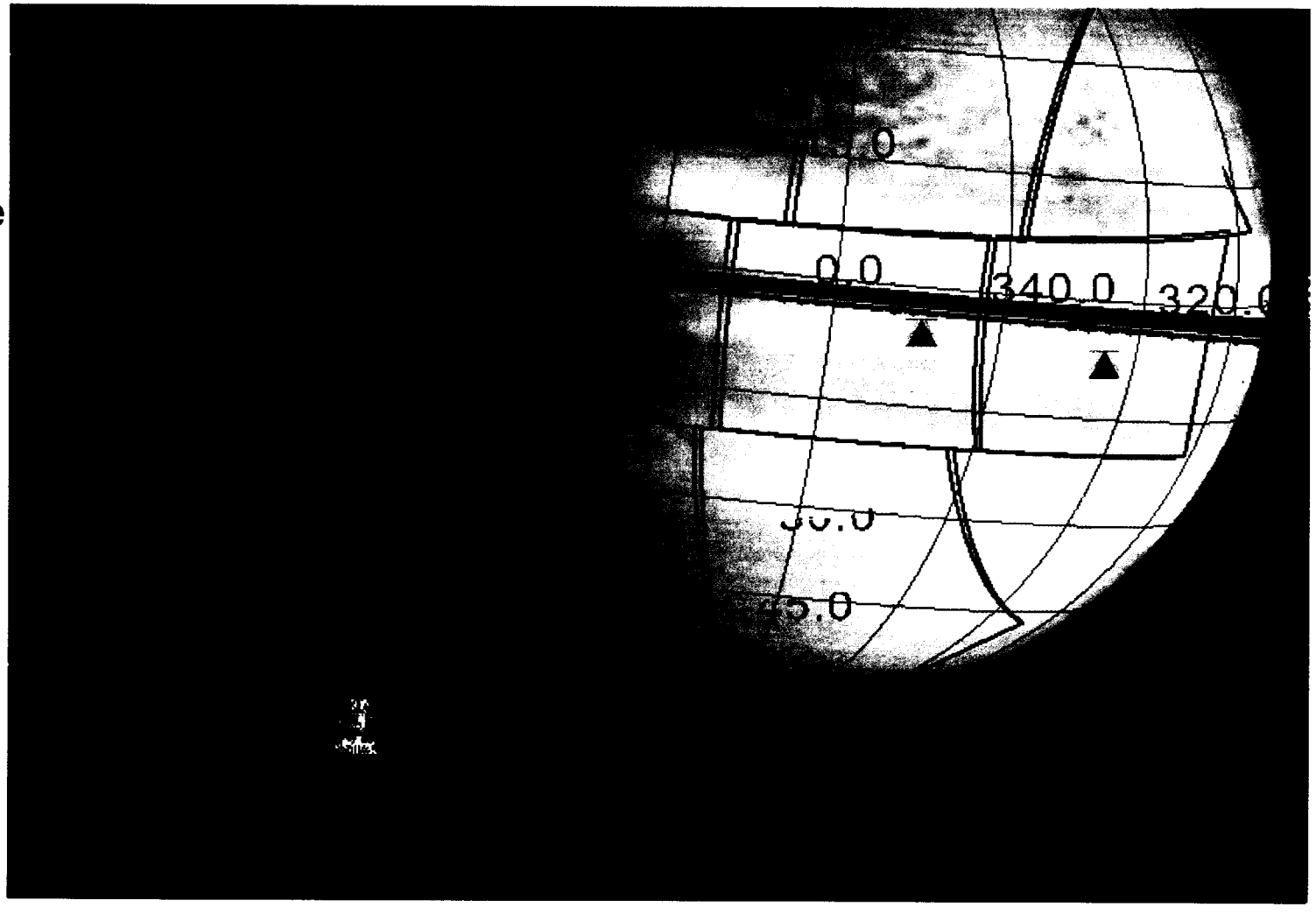
Name	Value	Default	Range	Comment
Activity Start Time	[redacted]	2005 Jun 08 ...		Time S/C starts to acquire target
Observation Start Time	2004 JAN 01 12:00:00.000	2005 Jun 08 ...		Valid S/C orientation is acquired
Observation End Time	[redacted]	2005 Jun 08 ...		Last time S/C orientation is maintained
Planned Duration	00:16:00.0	00:16:00.0		Total time allocated for the activity
Activity Duration	[redacted]	00:00:01		Total time calculated from parameters
Targeting Allowance	0:05:00.000	0:05:00.000		Time to acquire target S/C attitude
Targeting Margin	0:05:00.000	0:05:00.000		Margin applied to Targeting Allowance
Observation Duration	[redacted]	0:01:00.000		Calculated duration of valid S/C orientation
Observation Margin	0:05:00.000	0:05:00.000		Observation Margin
Step Interval	00:00:01	00:00:01		Frequency of calculations
Primary Target	SATURN Center	SATURN Cen...		Tracking reference point
Secondary Target	Align to SATURN pole	Align to SATU...		Used to specify S/C orientaiton around Primary ...
Target Offsets	X:0 deg;Y:0 deg;Z:0 deg	X:0 deg;Y:0 d...		Target Offsets
Primary Observer	S/C X Axis	S/C X Axis	S/C X Axis,S/C -X Axi...	Vector pointed at Primary Target + Offsets
Secondary Observer	S/C Z Axis	S/C Z Axis	S/C X Axis,S/C -X Axi...	Secondary Observer
Mosaic Specification	Flyback;1per strip;1 total; angles ...	Flyback;1per ...		Detailed mosaic parameters
Target Motion Compensation	OFF	OFF	ON,OFF	Tracking of the target during observation

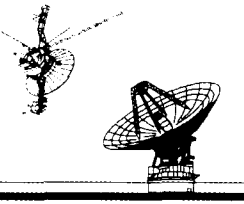
Observation design screen of SOA allows the user to specify the time, duration, target, instrument, and style of observation. Additional input screens accept detailed mosaic information.

Example mosaic showing the footprints of the Cassini Wide Angle Camera. Pink footprints indicate intercepts on the target body. Yellow footprints show the pointing in inertial space.



The same mosaic viewed from outside the spacecraft. Here, scientists can see the orientation of the spacecraft for possible secondary measurements.



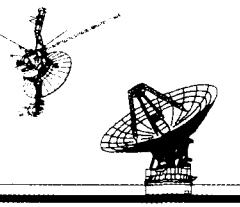


Opportunity Search | Observation | Flight Rules | Data Output | Communications | Global/Kernel | [illegible]

Default Activity Rules: All On | New/Edit Rule | Delete Rule | Load Rules | Save Rules

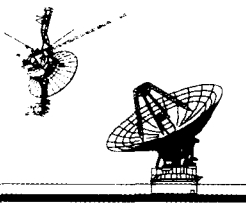
Rule Name	Enabled	Rule Expression	Description
AngleTest	☐	Angle	ISS WAC 5 deg of Sun
AngleTest20min	☑	Angle	ISS WAC 5 deg of Sun for 20 min
AngleTest30min	☐	Angle	ISS WAC 5 deg of Sun for 30 min
AngleASDTest	☐	Angle + ASD	ISS NAC 2 deg of Saturn
AngleASDTest2hr	☐	Angle + ASD	ISS NAC 2 deg of Saturn for 2 hours
AngleASDTest1day	☐	Angle + ASD	ISS NAC 2 deg of Saturn for 1 day
AngleASDTest2day	☐	Angle + ASD	ISS NAC 2 deg of Saturn for 2 day
AngleDistanceTest1	☐	Angle + Distance	ISS WAC 5 deg of Sun from 4-5 AU
AngleDistanceTest2	☑	Angle + Distance	ISS WAC 5 deg of Sun from 5-12 AU
AngleASDTest2	☐	Angle + ASD	ISS NAC between 2 & 4 deg of Saturn
AngleASDTest3	☐	Angle + ASD	ISS NAC between 4 & 6 deg
AngleASDDistanceTest1	☑	Angle + ASD + Distance	ISS NAC 2 deg of Saturn & Cassini within 1 million km
AngleASDDistanceTest2	☐	Angle + ASD + Distance	ISS NAC 2 deg of Saturn & Cassini between 1-5 million km
AngleASDDistanceTest3	☐	(Angle + ASD AND Distance)	ISS NAC 2 deg of Saturn s/c between 4-5 AU
AngleASDDistanceTest4	☐	(Angle + ASD AND Distance)	ISS NAC 2 deg of Saturn s/c between 5-12 AU
CompoundAngleTest	☑	(Angle OR Angle OR Angle)	ISS WAC multiple Sun conditions
FR07B4	☑	Angle + ASD + Distance	
rateTest1	☑	TurnRate	max rate = 0.0016 rad/s (default)
accelTest1	☑	**TurnAccel**	**max accel = 1.0E-5 rad/s/s (default)**
rateTest2	☐	TurnRate	max rate = 0.0001 rad/s
accelTest2	☐	TurnAccel	max accel = 10 rad/s/s
accelTest3	☐	TurnAccel	max accel = 8.0E-6 rad/s/s
ruleTest1	☑	Angle + ASD	ISS WAS RAD sun constraint

The constraint checking screen of SOA allows the user to define and control constraints that observations must meet. All violations of these constraints are identified by SOA in a time-ordered listing generated on the observation design screen.



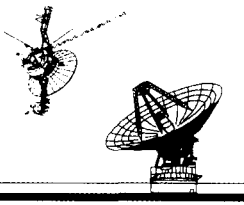
SOA Capabilities (cont.)

- Communications
  - Communicate opportunity & design results to other software tools in the uplink process.
    - Reads and writes the standard Spacecraft Activity Sequence File (SASF) format
    - Interaction with Activity Plan Generator (APGEN) timeline software to work within the "science plan."
    - Interaction with Seq_Pointer (simulates actual spacecraft hardware and software) for more detailed constraint checking.
    - Interaction with Seq_Gen (generates uplink files) to become part of the official sequence product.
  - First SEQ tool to be designed from the beginning to communicate with other tools.



SOA Capabilities (cont.)

- Ancillary Data Output
  - Generate data files with geometric information as a function of time with user-customized parameter list for any period of time, or for an observation.
  - Plot ancillary geometric data for any period of time.
  - Provides complementary method for identifying observation opportunities and for validating geometry for designed observations.



Opportunity Search | Flight Rules | Data Output | Communications | Global/Kernel

Source: Trajectory Related

Start Time: 2005 Jun 08 12:00:00.000 End Time: 2005 JUN 08 13:00:00.000

Data Interval: 00:10:00 Time Format: (•) UTC ( ) ISO DOY ( ) ISO SFOC

Target: SATURN Target Coordinate System: Planetocentric

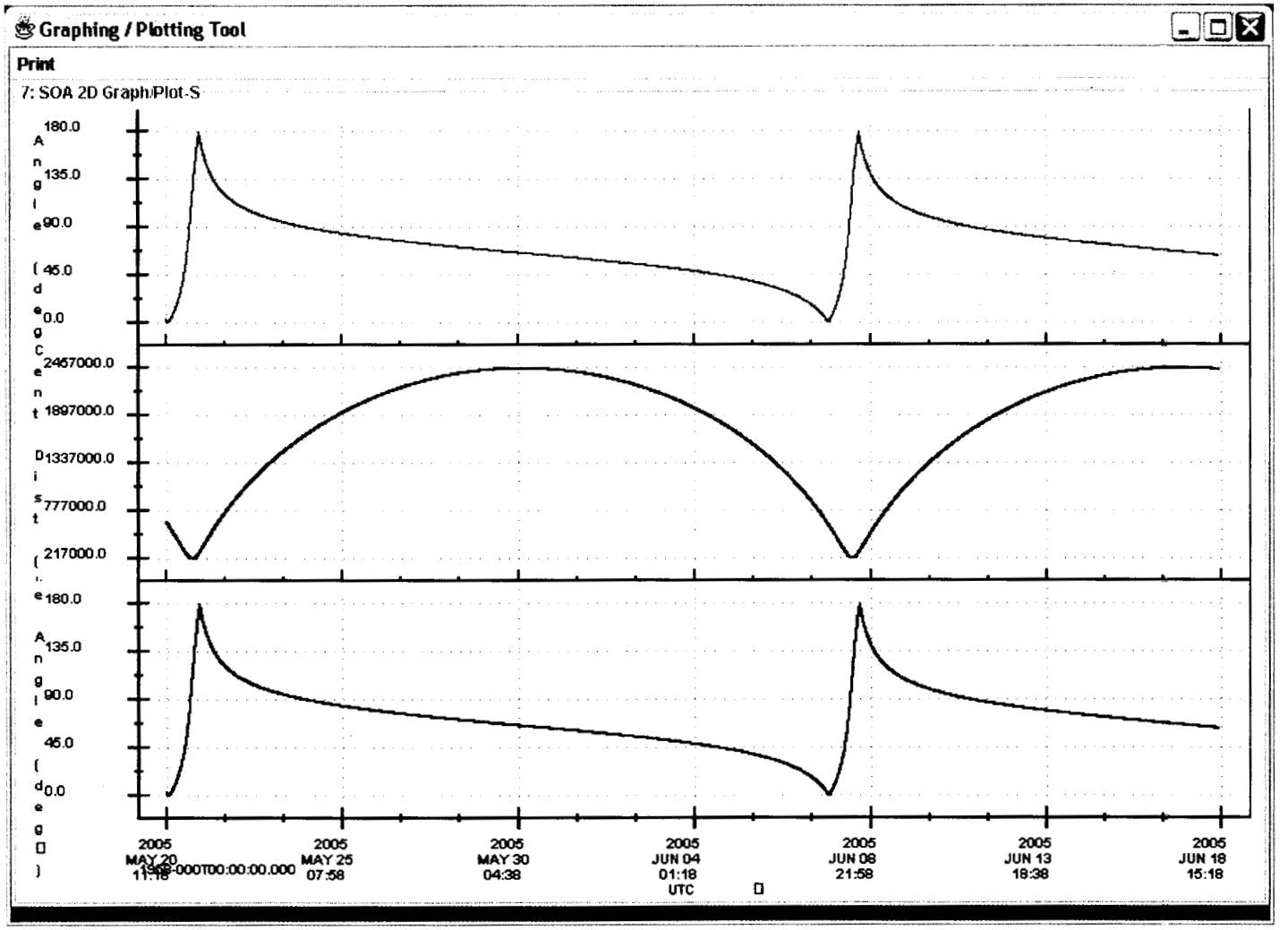
[ ] Angular Semi-Diameter (•) deg ( ) rad	[ ] S/C Altitude (•) km ( ) planetary radii
[ ] Dust RAM Head Ra/Dec (•) deg ( ) rad	[ ] S/C Dist. to Body Center (•) km ( ) planetary radii
[ ] Dust RAM Tail Ra/Dec (•) deg ( ) rad	[ ] S/C RAM Head Ra/Dec (•) deg ( ) rad
[ ] Dust Velocity Magnitude (•) km/s	[ ] S/C RAM Tail Ra/Dec (•) deg ( ) rad
[ ] Mag Field Magnitude (•) nT	[ ] S/C Velocity Magnitude (•) km/s
[ ] MagField Vector Head Ra/Dec (•) deg ( ) rad	[ ] Solar Incidence Angle (sub S/C point) (•) deg ( ) rad
[ ] MagField Vector Tail Ra/Dec (•) deg ( ) rad	[ ] Sub Reflection Lat/Lon (•) deg ( ) rad
[ ] Phase Angle (sub S/C point) (•) deg ( ) rad	[ ] Sub S/C Lat/Lon (•) deg ( ) rad
[ ] Plasma RAM Head Ra/Dec (•) deg ( ) rad	[ ] Sub Solar Lat/Lon (•) deg ( ) rad
[ ] Plasma RAM Tail Ra/Dec (•) deg ( ) rad	[ ] Target Angular Rate (•) mrad/s ( ) degrees/s
[ ] Plasma Velocity Magnitude (•) km/s	[ ] Target Ra/Dec (sub S/C point) (•) deg ( ) rad

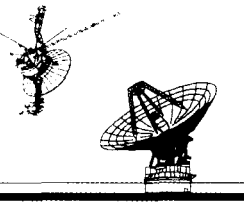
OUTPUT PLOT PLOT Help

Select or customize ancillary data for plotting or file output.

Example of stacked plot of ancillary geometric data:

phase angle, solar incidence angle, and distance from Saturn as functions of time.





SOA's Present and Future

- **Current Mission Support**
  - SOA is being used by the Cassini project, an international planetary spacecraft with a four year orbital tour at Saturn beginning July 1, 2004. Cassini scientists have been involved in detailed tour planning for more than 6 years. SOA is making observation design and planning more efficient in a time-constrained mission environment.
  - SOA's ability to show the same information in multiple ways (multiple visualization formats, data plots, listings, and file output) are essential when meeting the needs of a broad and diverse user community such as the Cassini Science Group.
- Multi-Mission Design
  - SOA is designed for use with any space mission. Project-specific capabilities are added to the core software as needed in the adaptation step.