

***NORTHROP GRUMMAN***

DEFINING THE FUTURE

# Automated Orbit Analysis

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AGI Users Exchange 28 August 2007

**Doug Cather**  
Systems Engineer  
Northrop Grumman Corporation

# Agenda

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- **History**
- **Description of AOA System**
- **Demo**

# History of AOA

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- In 1990, Northrop Grumman developed a system known as **AUTOMated Orbit Determination (AUTOOD)** which was written for a **VAX/VMS** computer architecture.
  - This system incorporated the collective experience and knowledge of many expert orbit analysts
    - Hundreds of quality checks
    - Historical trending used in the checks
    - Wrapped NG proprietary orbit determination software
  - This system has been continually improved and customers are extremely satisfied with its features and performance.

# History of AOA (cont)

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- In 2005, NG became a member of the Mobile User Objective System (MUOS) team and one of the NG tasks was to provide an automated orbit analysis system with the following characteristics:
  - COTS based
  - Database driven
  - Automated and unattended operations
  - Tight ephemeris accuracy requirements
  - Complex station-keeping strategy implemented so as to simplify the station-keeping planning task

# History of AOA (cont)

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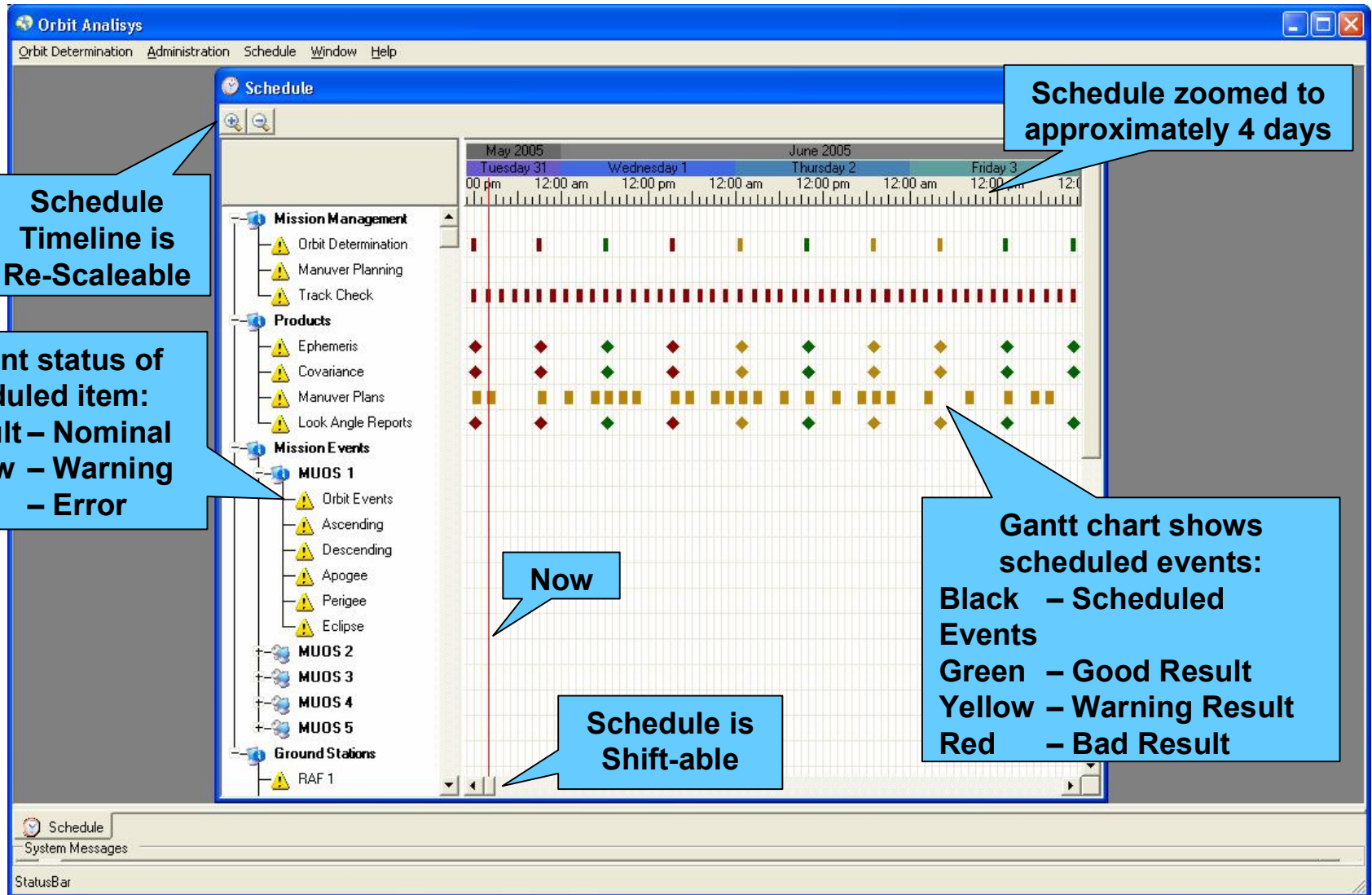
- **Based on the legacy AUTOOD system and the new MUOS requirements, an Automated Orbit Analysis (AOA) software system was designed and implemented.**
  - Uses AGI's STK and ODTK to perform all of the orbit related calculations
    - STK/Astrogator used for station-keeping planning
    - ODTK used for orbit determination
    - STK/Pro used to generate most orbit related products for internal and external interfaces
    - MySQL used for database storage

# Automation

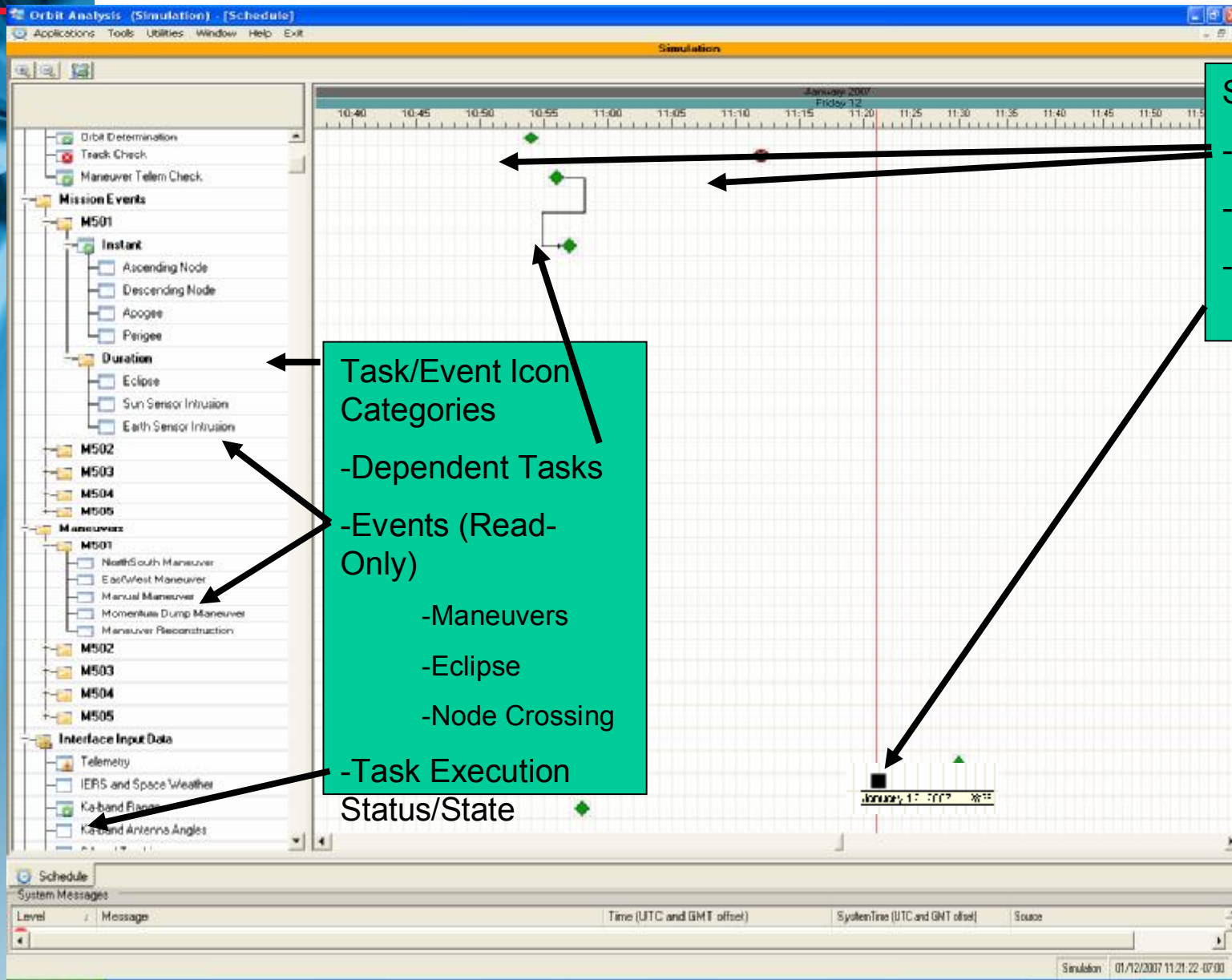
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- **Provides scheduling**
- **Monitoring capabilities**
- **Multiple Security levels**
  - Viewer Only (read permission only)
  - OA (perform OD, schedule tasks, database read/write, station-keeping planning, etc)
  - Senior OA (all of above + set rules, give permissions, add steps or checks, etc)
- **Maintains rules for quality assurance checks**
- **Data handling and archiving**
- **Status viewing capabilities**
- **Master dataset extraction tools**

# Automated Orbit Analysis Situational Awareness



# OA System Schedule



Schedule Icons

- Completion Status
- Execution State
- Scheduled
- Metadata

Task/Event Icon Categories

- Dependent Tasks
- Events (Read-Only)
- Maneuvers
- Eclipse
- Node Crossing

-Task Execution Status/State

# Database Description

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- **Databases contain:**
  - Rules for automation (i.e. schedule, frequency, tasks to be performed)
  - OD quality rules (i.e. overlap checks, historical trends, etc)
  - Master datasets
    - Ephemeris
    - Covariance
    - Orbit Events (i.e. eclipse, node crossings, rise/set, maneuvers, etc)
  - OD Trending data (i.e. solar radiation pressure solved-for values, tracking data biases solved-for values, etc)

# Task Scheduling (Tab 1)

**Task Scheduling**

+ Add Follow-Up - Remove Follow-Up

Schedule | Scheduled Task

Range

Start on: January 12, 2007 11:21:00

End after 1 occurrences

End by January 12, 2007 11:22:00

No End Date

Auto Execute  Modifiable by other schedule items  Read-only

OK Cancel

Schedule a Task

- Single Instance

- Series

**Task Scheduling**

+ Add Follow-Up - Remove Follow-Up

Schedule | Scheduled Task

Range

Start on: January 12, 2007 11:21:00

End after 3 occurrences

End by January 12, 2007 11:22:00

No End Date

Frequency

Hourly/Minutely Every 1 minute(s) of the hour

Daily/Weekly

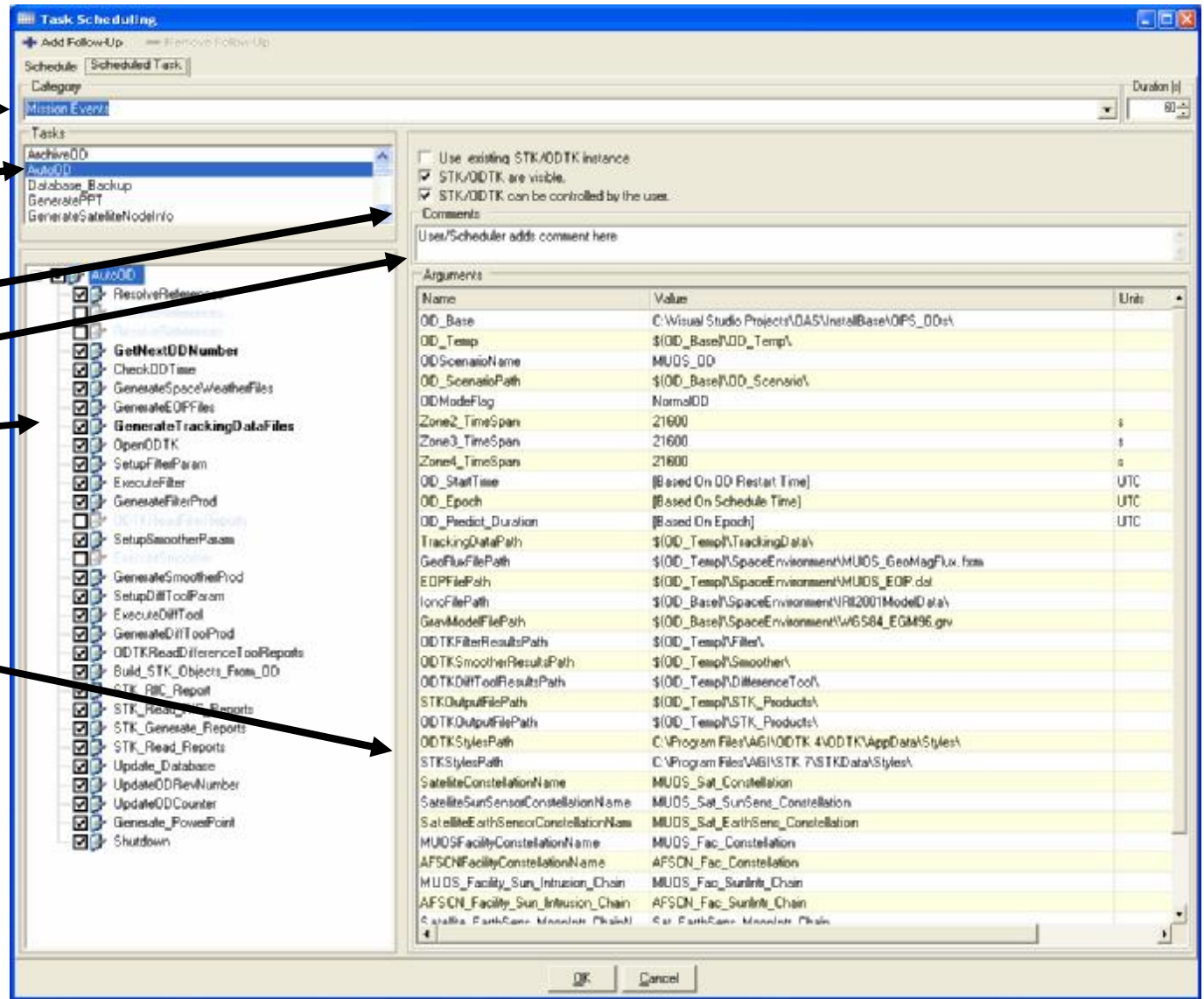
Monthly

Yearly

Auto Execute  Modifiable by other schedule items  Read-only  Interface Task(s)

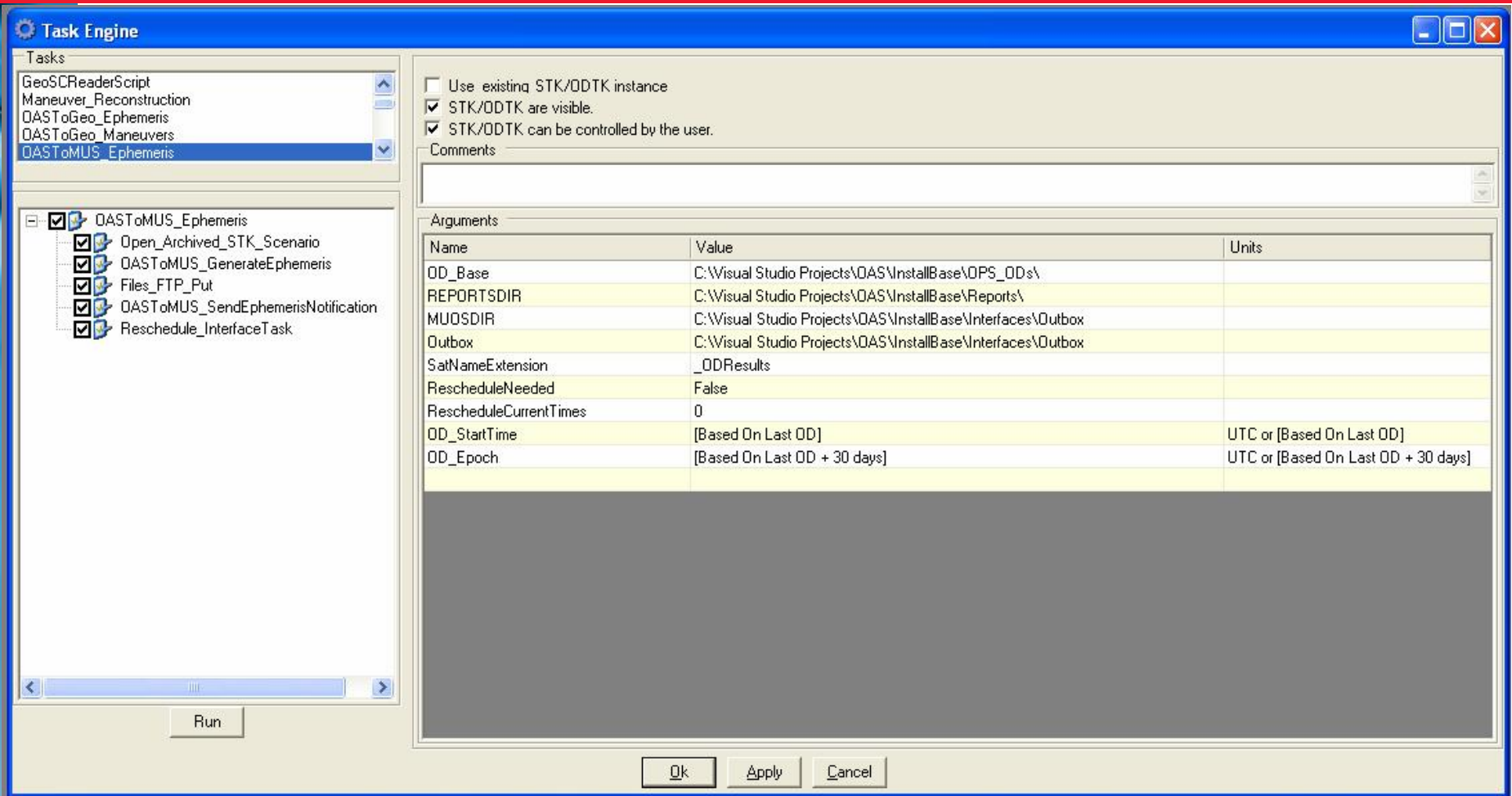
OK Cancel

# Task Scheduling (Tab 2)



- Category on Schedule (for Icon)
- Task Selection
- COTS visibility during Task Execution
- Comment Field
- Task Execution Steps
- Enable/Disable
- Task/Step Configurable Arguments (OA an Senior OA Editable)

# Task Engine



-Similar to Task Scheduling (Tab 2)

- Senior OA ability to modify baseline Tasks (available in all modes)
- Available to OA in Simulation and Test modes, for training.

# Task Modification

The screenshot displays the Task Engine interface with a task tree on the left and a configuration panel on the right. A green callout box labeled "Task Modifications" points to a context menu with the following options:

- Add
- Rename F2
- Delete Step Del
- Step Statistics Ctrl+S

Another green callout box labeled "Script/Step Modifications" points to a context menu with the following options:

- Edit Script Ctrl+E
- Delete Step Del
- Step Statistics Ctrl+S

The configuration panel on the right includes a "Script Path" field with the value "C:\Visual Studio Projects\OAS\InstallBase\TaskBase\InterfaceScripts\OASToMUS\_SendEphemerisNotification.vb" and an "Arguments" table:

Name	Value	Units
OASToMUS_EphemerisData.IP	127.0.0.1	
OASToMUS_EphemerisData.Port	8000	
OASToMUS_EphemerisData.Messag	301	

# Step/Script Editing

The screenshot shows the Automation Script Editor window. On the left, there is a 'Script Arguments' table with a single row containing an asterisk (\*). The main area displays a VB.NET script with XML comments and code for a class named OASToMUS\_SendEphemerisNotification. The script includes comments for history, summary, and parameters, and a Main function that checks for reschedule needs and loops through interface files.

Name	Value
*	

```
''' </summary>
''' <remarks>
''' </remarks>
''' <history>
''' [s392240] 6/19/2006 Created
''' </history>
'''
-----
Public Class OASToMUS_SendEphemerisNotification
    Inherits ScriptingInterfaces.Script

    ' IP of TT&C computer
    Private ip As String = ""

    ' Port on TT&C computer
    Private port As Integer = -1

    ' Type of message sent (server gets from app.config)
    Private messageType As Integer = -1

    '''
    -----
    ''' <summary>
    ''' Provides the starting point for the task.
    ''' </summary>
    ''' <param name="args">The args passed in.</param>
    ''' <returns>Success/Failure</returns>
    ''' <remarks>
    ''' </remarks>
    '''
    -----
    Protected Overrides Function Main(ByVal args As OACCommon.StringDictionary) As Boolean

        Try

            Dim rescheduleNeeded As Boolean = DirectCast(Variables("RescheduleNeeded"), Boolean)

            ' if we failed to FTP files, we need to reschedule the task and don't want to send no
            If rescheduleNeeded Then Return True

            ' Loop through the interface files, sending notification for each with a pause
            For Each filePath As String In DirectCast(Variables("NotificationFiles"), Hashtable).Keys

                If File.Exists(filePath) Then
```

- Scripts in VB.net  
- Options for modification of a Task Script/Step.

# Maneuver Planning

**Maneuver Planning**

Mission ID: M501  
 Station Longitude (Deg): 0  
 Last Ephemeris: 1/1/2015 6:00:00 AM

**Limits**

	Minimum	Maximum
Longitude Limit	-177.1	-176.9
Longitude boundry crossing unknown		
Guard Band Lon	-177.08	-176.92
Guard band boundry crossing unknown		
Inclination (Deg)	2.5	5
Inclination boundry crossing unknown		
Eccentricity	0.005	0.006
Eccentricity boundry crossing unknown		
Argument of Perigee	174.8	185.2
Argument of Perigee boundry crossing unknown		

**Commands**

New Maneuver Remove  
 Protect Commit  
 Accept Changes Cancel

**Display Options**

- Hide Committed Maneuvers
- Hide Protected Maneuvers
- Hide Planned Maneuvers
- Hide Manual Maneuvers
- Hide Momentum Maneuvers
- Hide North / South Maneuvers
- Hide East / West Maneuvers
- Make STK visible

Drift Rate vs Longitude | Longitude vs Time | Drift Rate vs Time | Eccentricity vs Time | RAAN vs Time

No Data Available

Ascending  
 Descending

Status	Maneuver	Type	Date & Time (UTC)	Magnitude (m)	Duration

# New Maneuver Plan

**Add a Maneuver**

Maneuver: East / West Station Keeping

Date to perform maneuver (UTC): Friday, January 02, 2015

Time between maneuvers (days): 14

Use default maneuver settings

Target Longitude: -177

Strategy: 1-Part

Thruster Set (part 1): East.All Control Set (part 1): East EWSK REA

Ephemeris prediction (days): 31

OK Cancel

**Add a Maneuver**

Maneuver: North / South Station Keeping

Date to perform maneuver (UTC): Friday, January 02, 2015

Use default maneuver settings

Duration (sec): 4915

Thruster Set (part 1): None Control Set (part 1): East NSSK REA

Ephemeris prediction (days): 31

OK Cancel

**Add a Maneuver**

Maneuver: Momentum Dump

Date to perform maneuver (UTC): Friday, January 02, 2015

Time (UTC): 1:48:34 PM

Thruster Set: None

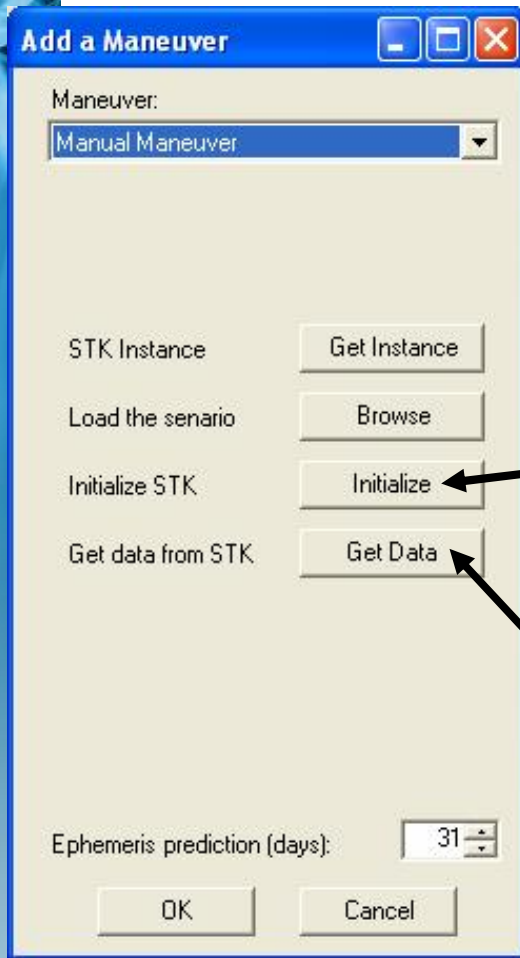
Control Thruster Set: East NSSK REA

Magnitude: 1

Ephemeris prediction (days): 31

OK Cancel

# Manual Maneuver



-Inputs most up-to-date ephemeris information into STK maneuver planning scenario

-User manually interacts with STK scenario to plan EOL and Relocation maneuvers

-Data for maneuvers is extracted from STK scenario and put into OAS database

-Maneuvers planned appear on Maneuver planning GUI and can be sent to MUS.

# Planned Maneuvers

Maneuver Planning

Mission ID:

Station Longitude (Deg):

Last Ephemeris: 1/1/2015 6:00:00 AM

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**Limits**

	Minimum	Maximum
Longitude Limit	<input type="text" value="-177.1"/>	<input type="text" value="-176.9"/>
Longitude in bounds through 2/1/2015 6:00:00 AM		
Guard Band Lon	<input type="text" value="-177.08"/>	<input type="text" value="-176.92"/>
Guard Band in bounds through 2/1/2015 6:00:00 AM		
Inclination (Deg)	<input type="text" value="2.5"/>	<input type="text" value="5"/>
Inclination in bounds through 2/1/2015 6:00:00 AM		
Eccentricity	<input type="text" value="0.005"/>	<input type="text" value="0.006"/>
Eccentricity in bounds through 2/1/2015 6:00:00 AM		
Argument of Perigee	<input type="text" value="174.8"/>	<input type="text" value="185.2"/>
Angle of Perigee in bounds through 2/1/2015 6:00:00 AM		

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**Commands**

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**Display Options**

- Hide Committed Maneuvers
- Hide Protected Maneuvers
- Hide Planned Maneuvers
- Hide Manual Maneuvers
- Hide Momentum Maneuvers
- Hide North / South Maneuvers
- Hide East / West Maneuvers
- Make STK visible

Drift Rate vs Longitude | Longitude vs Time | Drift Rate vs Time | Eccentricity vs Time | RAAN vs Time | Arg Of Perigee vs Time | Eccentricity vs Arg Of Perigee | Inclination vs RAAN

ChartFX License has Expired

Status	Maneuver	Type	Date & Time (UTC)	Magnitude (m)	Duration (sec)	Description
Planned	1	EastWest	4 Jan 2015 22:25:52.194	0.117723	4.26	
Planned	2	EastWest	21 Jan 2015 21:11:34.904	0.079172	2.875	

# Changing Maneuver State

**Maneuver Planning**

Mission ID: M501  
 Station Longitude (Deg): 0  
 Last Ephemeris: 1/1/2015 6:00:00 AM

**Limits**

Parameter	Minimum	Maximum
Longitude Limit	-177.1	-176.9
Guard Band Lon	-177.08	-176.92
Inclination (Deg)	2.5	5
Eccentricity	0.005	0.006
Argument of Perigee	174.8	185.2

**Commands**

New Maneuver Remove  
 Protect Commit  
 Accept Changes Cancel

**Display Options**

- Hide Committed Maneuvers
- Hide Protected Maneuvers
- Hide Planned Maneuvers
- Hide Manual Maneuvers
- Hide Momentum Maneuvers
- Hide North / South Maneuvers
- Hide East / West Maneuvers
- Make STK visible

**Maneuver Table**

Status	Maneuver	Type	Date & Time (UTC)	Magnitude (m)	Duration (sec)	Description
Protected	1	EastWest	4 Jan 2015 22:25:52.194	0.117723	4.26	
Protected	2	EastWest	21 Jan 2015 21:11:34.904	0.079172	2.875	
Protected	3	NorthSouth	2 Feb 2015 00:53:12.181	0	4915	

**Callout Box:**

- Chart FX Graphing options
- Satellite State vector used to plan future maneuvers
- Out of Tolerance limits for orbit parameters
- State of Maneuvers identified

# Changing Maneuver State

Maneuver Planning
[Min] [Max] [Close]

Mission ID:

Station Longitude (Deg):

Last Ephemeris: 1/1/2015 6:00:00 AM

**Limits**

	Minimum	Maximum
Longitude Limit	<input type="text" value="-177.1"/>	<input type="text" value="-176.9"/>
Longitude in bounds through 2/1/2015 6:00:00 AM		
Guard Band Lon	<input type="text" value="-177.08"/>	<input type="text" value="-176.92"/>
Guard Band in bounds through 2/1/2015 6:00:00 AM		
Inclination (Deg)	<input type="text" value="2.5"/>	<input type="text" value="5"/>
Inclination in bounds through 2/1/2015 6:00:00 AM		
Eccentricity	<input type="text" value="0.005"/>	<input type="text" value="0.006"/>
Eccentricity in bounds through 2/1/2015 6:00:00 AM		
Argument of Perigee	<input type="text" value="174.8"/>	<input type="text" value="185.2"/>
Angle of Perigee in bounds through 2/1/2015 6:00:00 AM		

**Commands**

**Display Options**

- Hide Committed Maneuvers
- Hide Protected Maneuvers
- Hide Planned Maneuvers
- Hide Manual Maneuvers
- Hide Momentum Maneuvers
- Hide North / South Maneuvers
- Hide East / West Maneuvers
- Make STK visible

Drift Rate vs Longitude | Longitude vs Time | Drift Rate vs Time | Eccentricity vs Time | RAAN vs Time | Arg Of Perigee vs Time | Eccentricity vs Arg Of Perigee | Inclination vs RAAN

[Print] [Zoom] [Tools]

-Committed maneuver identifies that MUS has been sent the Maneuver Plan. (Only a Senior OA can undo this Commit, since it requires coordination with MUS.)

Ascending  
 Descending

Status	Maneuver	Type	Date & Time (UTC)	Magnitude (m)	Duration (sec)	Description
Committed	1	EastWest	4 Jan 2015 22:25:52.194	0.117723	4.26	
Committed	2	EastWest	21 Jan 2015 21:11:34.904	0.079172	2.875	
Protected	3	NorthSouth	2 Feb 2015 00:53:12.181	0	4915	



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# Demo