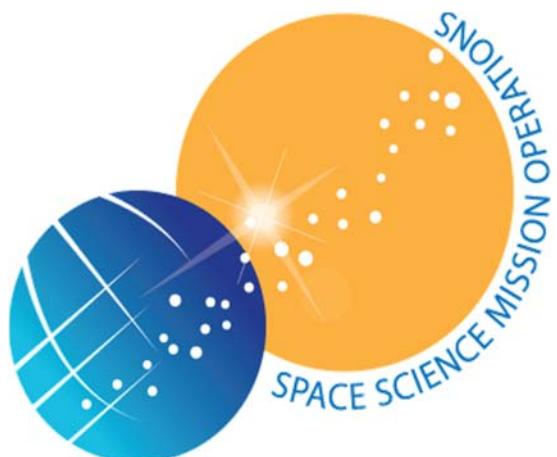




The Virtualized Multi-Mission Operations Center (vMMOC) and its Cloud Services



Presented by

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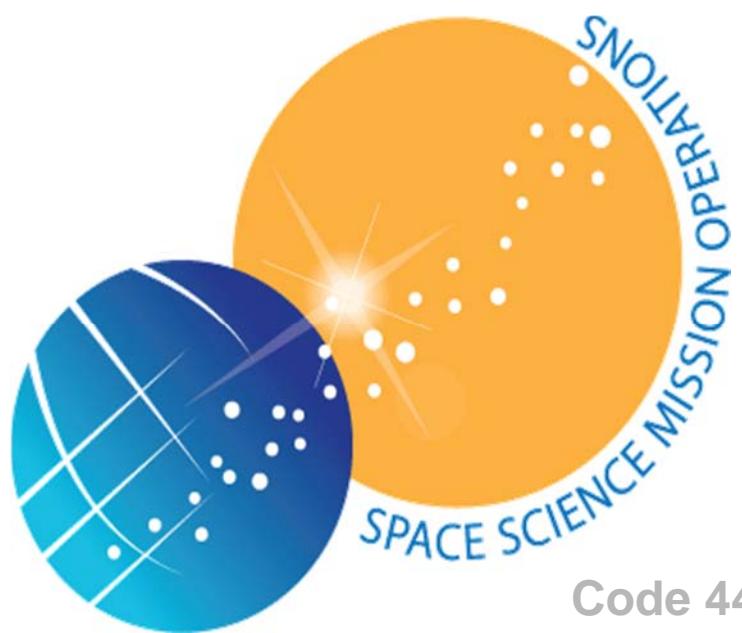
Objective of Presentation



- **What is Space Science Mission Operations (SSMO)?**
- **What is the vMMOC?**
- **Available vMMOC Services**
- **“Looking Beyond the Horizon”**



What is Space Science Mission Operations (SSMO)?



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SPACE FLIGHT CENTER

Code 444.0



What is Space Science Mission Operations (SSMO)?



- **SSMO** provides project oversight for 19 NASA *space science* missions for which GSFC is responsible
- **SSMO** has a diverse set of missions:
 - heritage/launch date
 - orbit regime
 - spacecraft bus type
 - mission profile
 - communication networks
 - In-house and Out of House Mission Operations Centers (MOCs)



SSMO Spacecraft in Operations



Mission	Launch Year	MOC Location	Science Type	# s/c	Orbit Regime	Catalog #
ACE	1997	GSFC	Heliophysics	1	L1	N/A
AIM	2007	LASP	Heliophysics	1	LEO	31304
ARTEMIS*	2007	UC Berkeley	Heliophysics	2	P1, lunar orbit; P2, Lunar Lagrange Point 1	30581, 30582
Fermi	2008	GSFC	Astrophysics	1	LEO	33053
IBEX	2008	Orbital	Heliophysics	1	HEO (T = 9 days)	33401
IRIS	2013	ARC	Heliophysics	1	LEO	
LRO	2009	GSFC	Planetary (Lunar)	1	Lunar Orbit	N/A
MAVEN	2013	LM - Denver	Planetary	1	Mars Orbit	N/A
MMS	2015	GSFC	Heliophysics	4	HEO	40482, 40483, 40484, 40485
OSIRIS-REx	2016	LM-Denver	Planetary	1	Heliocentric	N/A
Van Allen Probes (RBSP)	2012	APL	Heliophysics	2	HEO	38752, 38753
RHESSI	2002	UC Berkeley	Heliophysics	1	LEO	27370
SDO	2010	GSFC	Heliophysics	1	GEO	36395
SOHO**	1995	GSFC	Heliophysics	1	L1	n/a
STEREO	2006	APL	Heliophysics	2	Heliocentric	n/a
Swift	2004	Penn State	Astrophysics	1	LEO	28485
THEMIS	2007	UC Berkeley	Heliophysics	3	HEO	305880, 30584, 30585
TIMED	2001	APL	Heliophysics	1	LEO	26998
WIND	1994	GSFC	Heliophysics	1	L1	n/a



What is the vMMOC?



What is the virtualized Multi-Mission Operations Center (vMMOC)?

The vMMOC's Objectives are ...

- *Rapid and efficient provisioning and orchestration of spacecraft mission operation environments.*
- *Break the barrier to mission operations and enhance accessibility*



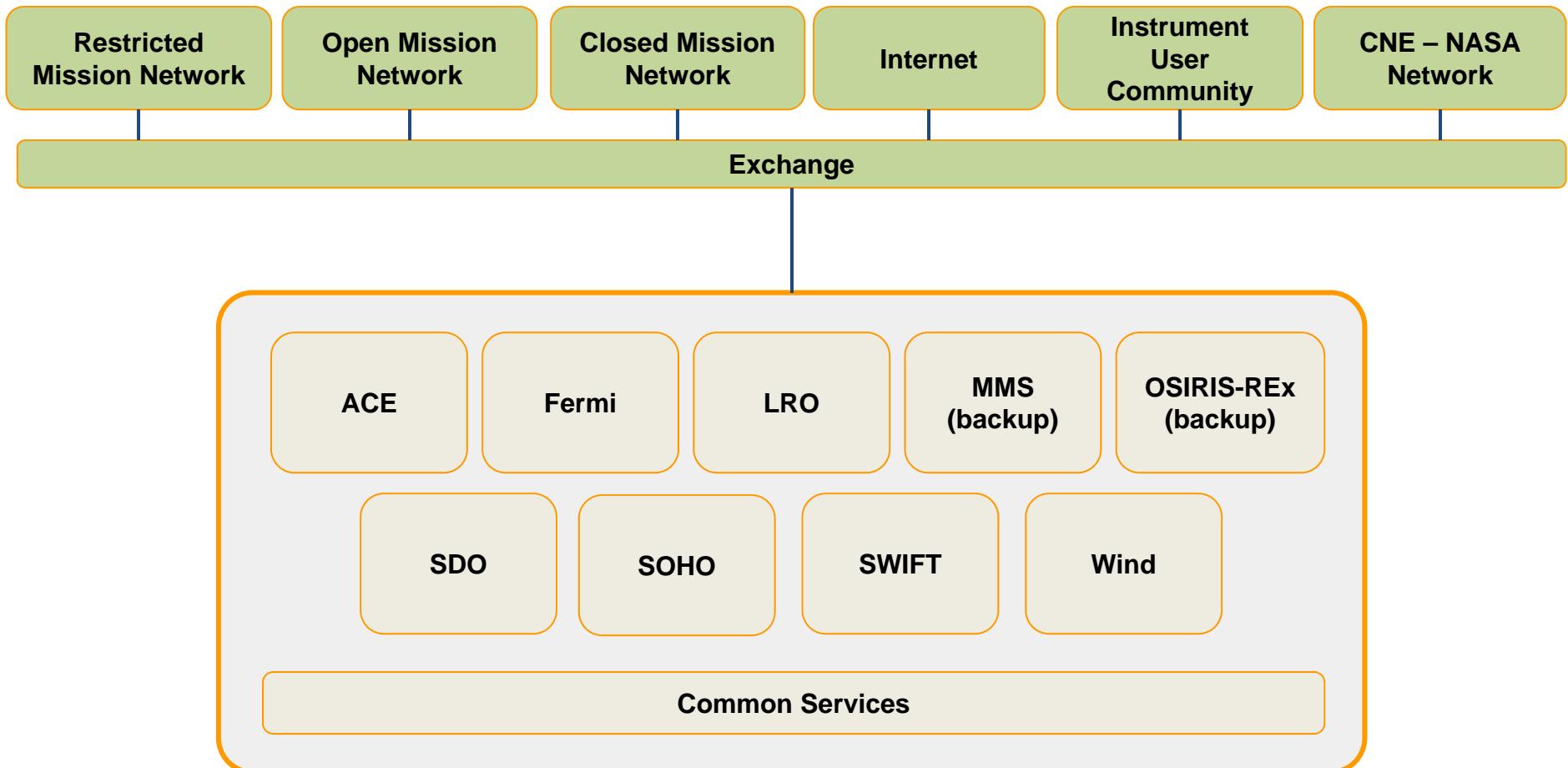
What is the vMMOC?



- **Multiple-missions Operated from one center**
- **Local virtualized infrastructure**
- **Access to a secure public cloud computing infrastructure**
- **Situational Awareness Dashboard (a SaaS)**
- **Telemetry as a Service (TaaS)**
 - Soon to be ***Telemetry, and Tracking as a Service (TTaaS)***
- **Navigation as a Service (NaaS)**



vMMOC's High Level Infrastructure





What is the vMMOC?



- **Shared:**
 - Infrastructure
 - Product formats
 - Networking interfaces
 - Workflows & Procedures
 - Security implementations
 - Hardware and software
 - Core staff
 - Lessons-learned
 - Culture

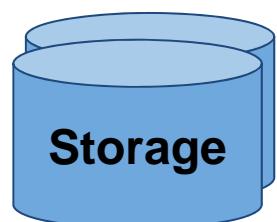


What is the vMMOC?



Private virtualized infrastructure

GSFC - SSMO

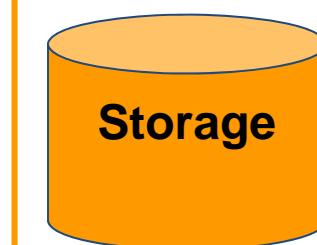


Data Producers & Consumers



Public Cloud Computing (secured)

AWS GovCloud





Situational Awareness Dashboard



Break the barrier to data access



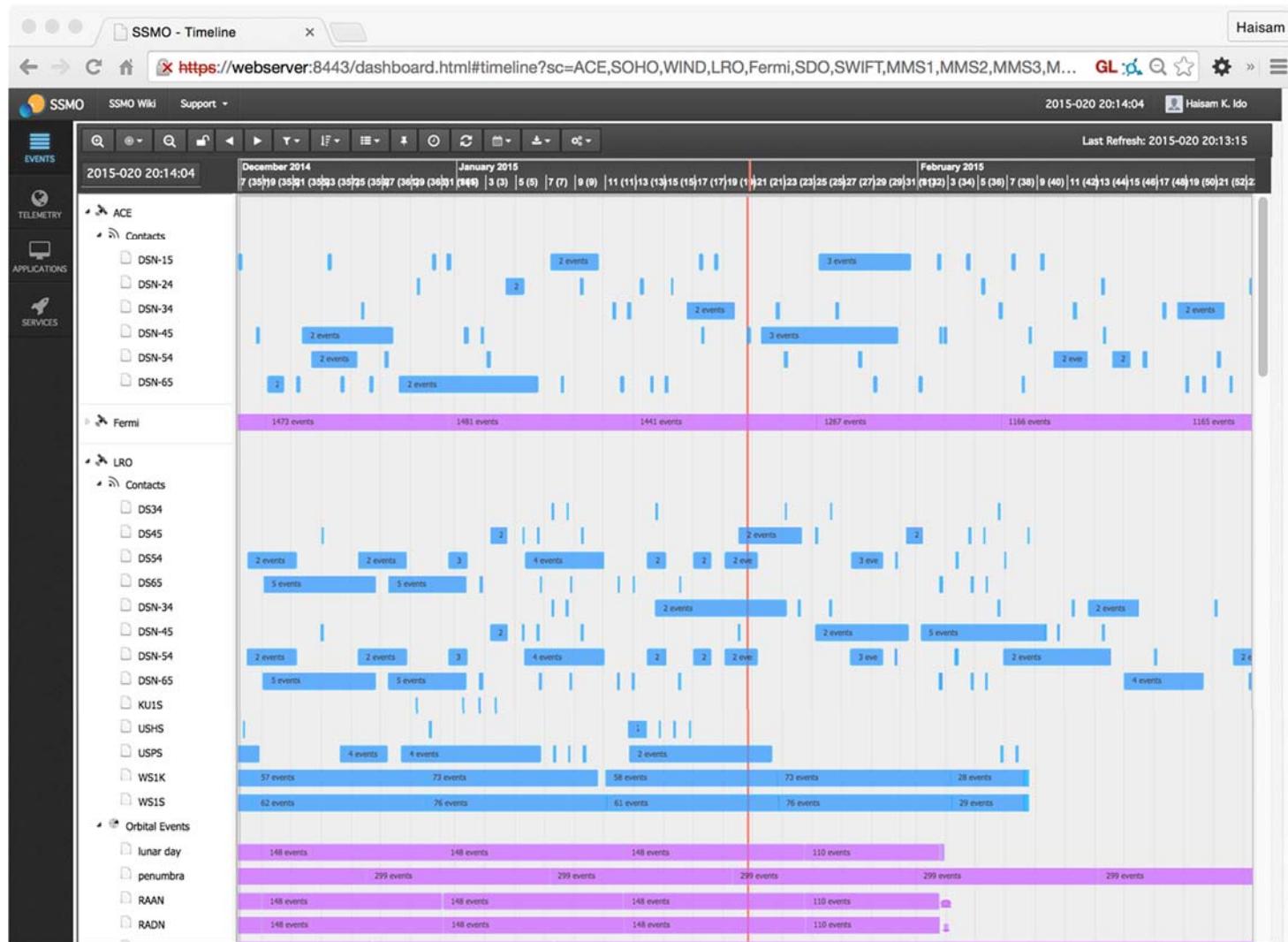
- **Provide local and remote users an integrated, situational awareness dashboard of major spacecraft and ground events**
 - Secure
 - Tailorable, self-service capability to access all spacecraft timelines
 - Liberate the data
 - Empower each engineer to tailor requests for any SSMO spacecraft
- **A web service based on NIST's Software as a Service (SaaS) model**



vMMOC Services - Situational Awareness Dashboard



A timeline view of ACE, Fermi and LRO

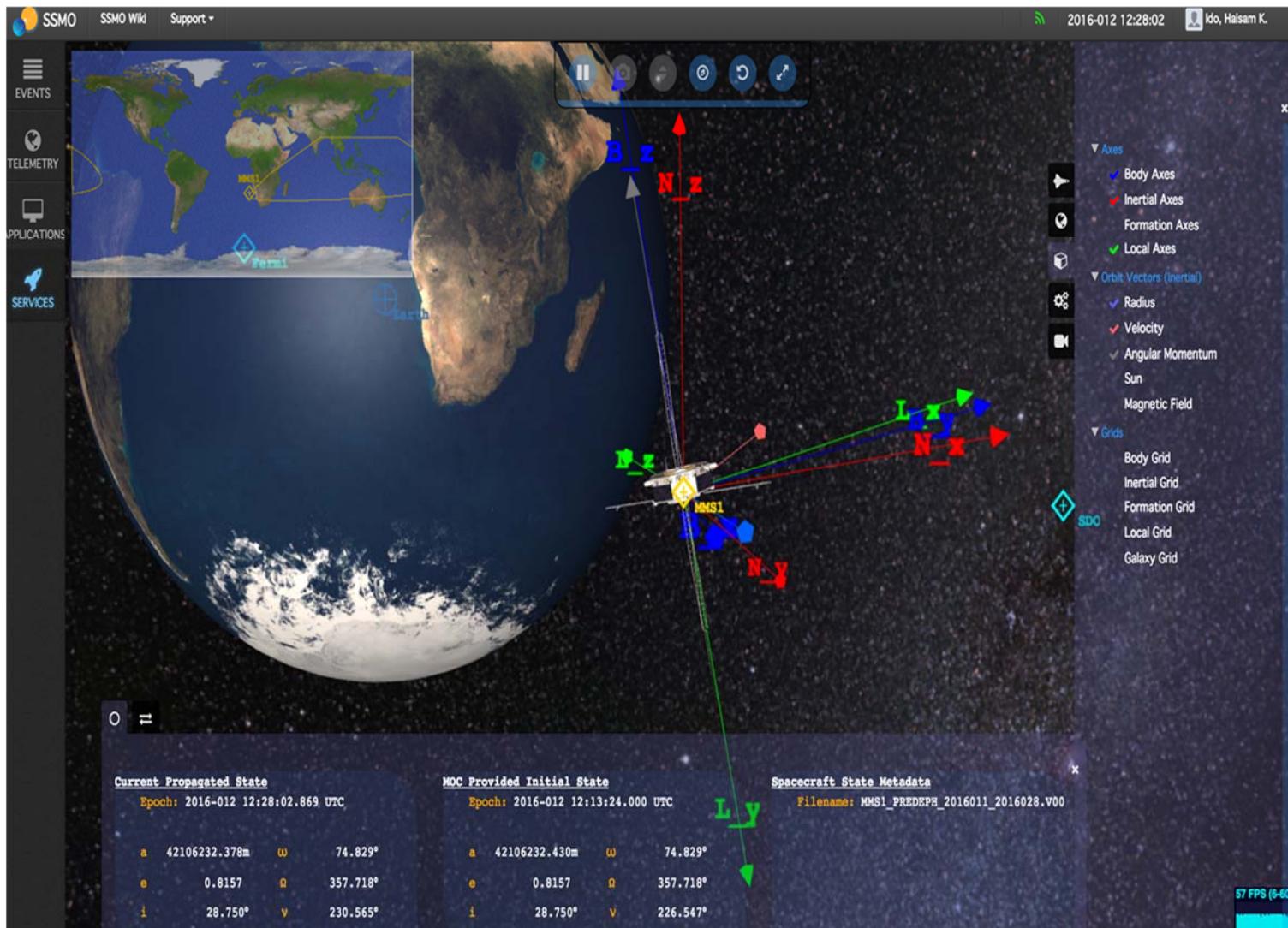




vMMOC Services - Situational Awareness Dashboard



A view of a closeup of MMS1

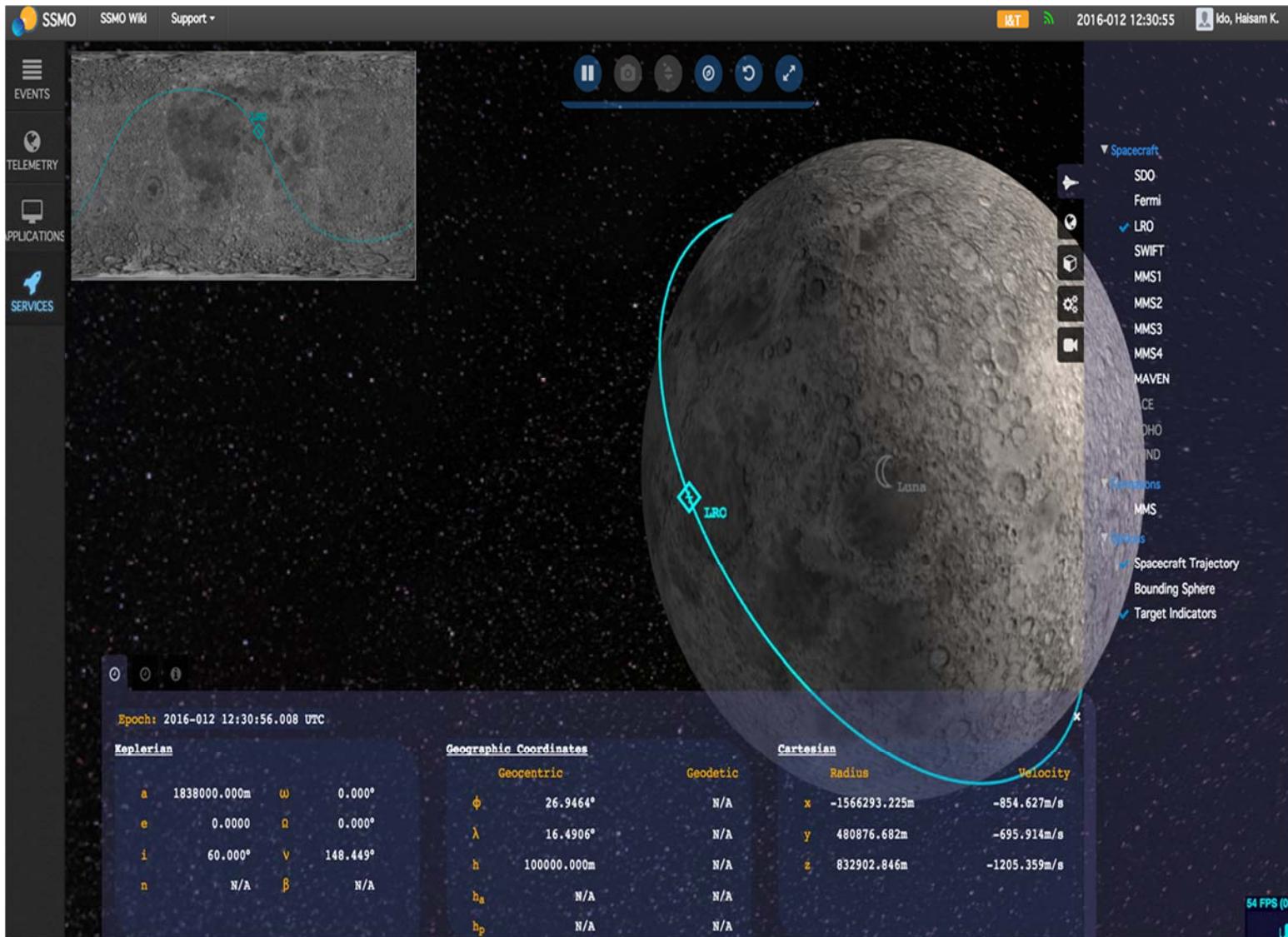




vMMOC Services - Situational Awareness Dashboard



A view of LRO





Execute General Mission Analysis Tool (GMAT) in the cloud

The screenshot shows a web-based interface for executing GMAT scripts. On the left, a sidebar lists various GMAT-related files in a tree view. The main area displays the content of the selected file, `Ex_HohmannTransfer.script`. This script defines a spacecraft with specific parameters like mass, position, and orientation, and creates a force model for a Hohmann transfer. At the bottom, a terminal window shows the output of the GMAT cloud execution, indicating the application has started and the build date. A message at the bottom right states "Execution of 'Ex_HohmannTransfer.script' has completed. (click to hide)".

```
1 % Script Mission - Hohmann Transfer Example
2 %
3 % This script demonstrates how to target a Hohmann Transfer
4 %
5 %
6 %----- Spacecraft -----
7 %
8 %
9 Create Spacecraft DefaultSC;
10 GMAT DefaultSC.DateFormat = 'TAIModJulian';
11 GMAT DefaultSC.Date = '2015-02-21T15:00:00';
12 GMAT DefaultSC.CoordinateSystem = 'EarthMJD2000Eq';
13 GMAT DefaultSC.DisplayStateType = 'Cartesian';
14 GMAT DefaultSC.DryMass = 1000;
15 GMAT DefaultSC.IX = 7100;
16 GMAT DefaultSC.IY = 0;
17 GMAT DefaultSC.IZ = 1300;
18 GMAT DefaultSC.IVX = 90;
19 GMAT DefaultSC.IVY = -35;
20 GMAT DefaultSC.IVZ = 1;
21 GMAT DefaultSC.DryMass = 850;
22 GMAT DefaultSC.Cd = 2.2;
23 GMAT DefaultSC.CS = 0.8;
24 GMAT DefaultSC.SapRate = 15;
25 GMAT DefaultSC.SRPArea = 1;
26 GMAT DefaultSC.WAFTId = -123456789;
27 GMAT DefaultSC.WAFTIdReferenceFrame = -123456789;
28 GMAT DefaultSC.Id = 'SatId';
29 GMAT DefaultSC.Attitude = 'CoordinateSystemFixed';
30 GMAT DefaultSC.ModelName = '../data/vehicle/models/aura.3ds';
31 GMAT DefaultSC.ModelOffsetX = 0;
32 GMAT DefaultSC.ModelOffsetY = 0;
33 GMAT DefaultSC.ModelOffsetZ = 0;
34 GMAT DefaultSC.ModelRotationX = 0;
35 GMAT DefaultSC.ModelRotationY = 0;
36 GMAT DefaultSC.ModelRotationZ = 0;
37 GMAT DefaultSC.ModelScale = 1;
38 GMAT DefaultSC.AttitudeDisplayStateType = 'Quaternion';
39 GMAT DefaultSC.AttitudeRateDisplayStateType = 'AngularVelocity';
40 GMAT DefaultSC.AttitudeCoordinateSystem = 'EarthMJD2000Eq';
41 %
42 %
43 %----- ForceModels and Propagators -----
44 %
45 Create ForceModel DefaultProp_ForceModel;
46 GMAT DefaultProp_ForceModel.CentralBody = 'Earth';
47 GMAT DefaultProp_ForceModel.PlanetPointing = 'Earth';
48 GMAT DefaultProp_ForceModel.PlanetScale = 'None';
49 GMAT DefaultProp_ForceModel.SEP = 'Off';
50 GMAT DefaultProp_ForceModel.RelativisticCorrection = 'Off';
51 GMAT DefaultProp_ForceModel.RotControl = 'RBSStep';
52 %
53 %
54 %----- Propagators -----
55 %
56 %
57
58 #GMATCloud Execution Started
59 **** GMAT Console Application ****
60
61 General Mission Analysis Tool
62 Console Based Version
63 Build Date: May 21 2014 11:27:50
64
65 Moderator is creating core engine...
66 ./../../../../GLOMAS/applications/gmat/plugins/libGMAT.dll
```



Telemetry as a Service (TaaS)



Break the barrier to data access



- **Provide local & remote users access to *telemetry & tracking***
 - Secure
 - Tailorable, self-service capability to access all SSMO spacecraft telemetry & tracking:
 - Liberate the data
 - Empower each engineer to tailor requests for any SSMO spacecraft
 - Each engineer can perform analysis without interfering with operations workflows
- A web service based on NIST's Software as a Service (SaaS) model



A view of the portal

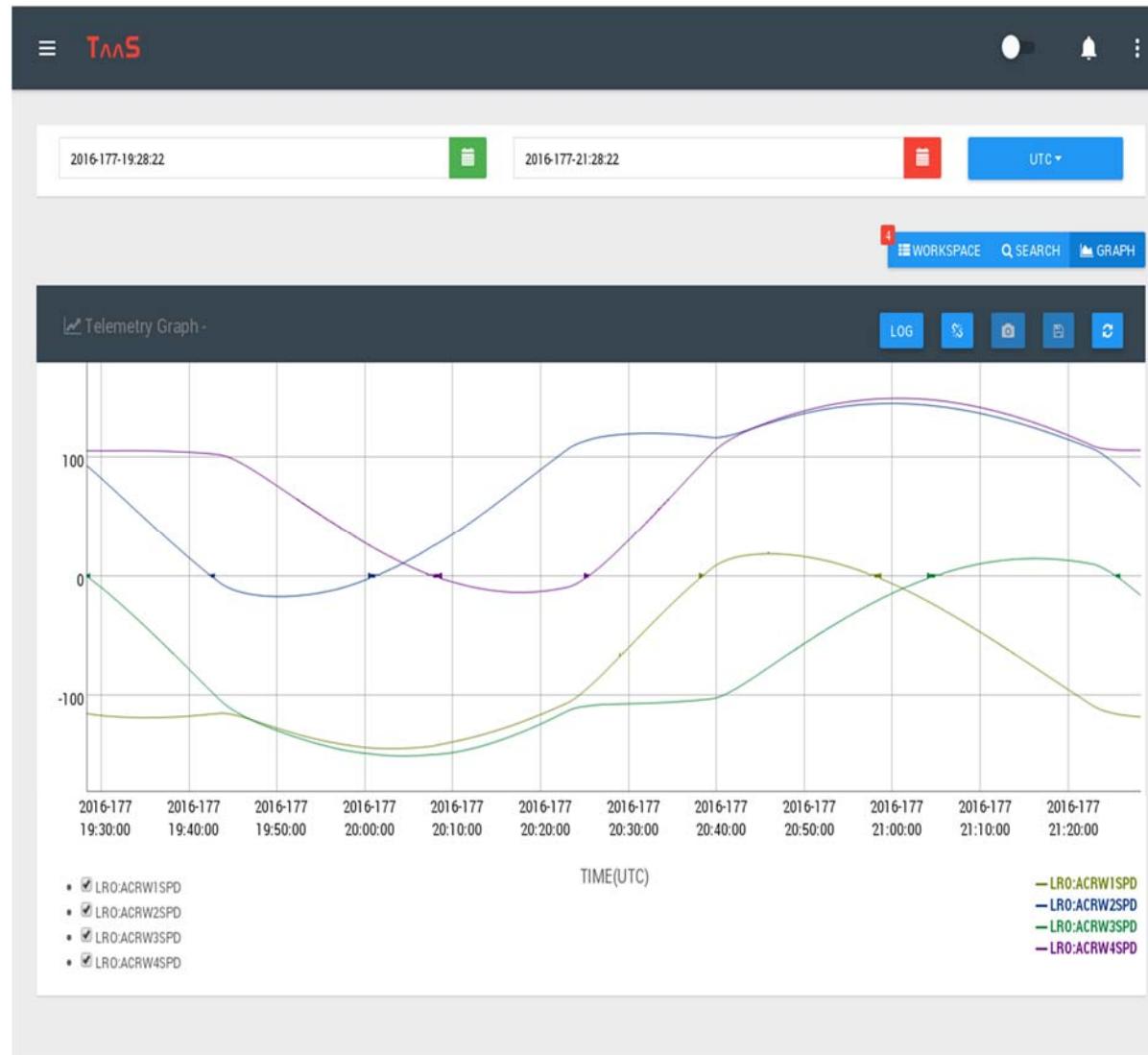
The screenshot shows the 'Selected Mnemonics' section of the portal. It lists mnemonics for several spacecraft, each with a checkbox, a packet ID, and a mnemonic description. The columns are labeled: SPACECRAFT, PACKET, MNEMONIC, and MNEMONIC DESCRIPTION.

SPACECRAFT	PACKET	MNEMONIC	MNEMONIC DESCRIPTION
<input type="checkbox"/>			
<input checked="" type="checkbox"/> Fermi	11	SAC_MODE	GNC_TLM_MODE Telemetry (SIANCILLARY GNC_MODE). Current spacecraft ACS mode
<input checked="" type="checkbox"/> LRO	203	ACRW1SPD	Reaction Wheel 1 Wheel Speed
<input checked="" type="checkbox"/> MMST	126	PSE_BATV	'PSE_PMC0_BATT_V' BATTERY MODULE ANALOG BATTERY VOLTAGE ; P306.8 pwr rtn to chs(+) 23 chs to pwr rtn(-)
<input checked="" type="checkbox"/> SDO	138	ACS_P_DIAG[1]	Kalman Filter covariance diagonal element 1,2,3,4,5,6.
<input checked="" type="checkbox"/> Swift	16	SAC_MODE	ACS_TLM_MODE Telemetry. Current spacecraft ACS mode
<input checked="" type="checkbox"/> Swift	16	SAC_MODE	ACS_TLM_MODE Telemetry. Current spacecraft ACS mode

At the bottom right of the table, there are buttons for page navigation: 10, 25, 50, 100.



A view of a plot of wheel speeds





Navigation as a Service (NaaS)



Break the barrier to data access



Navigate the Spacecraft in Support of Mission Operations

Navigation Services

- Maneuver planning
- Maneuver execution
- Maneuver reconstruction
- Orbit estimation & control
- Attitude estimation & control

Scheduling & Planning in Support of Navigation

- Maneuvers
- Network Availability
- Antenna Availability
- AOS/LOS
- Shadows
- Interference
- Tracking



“Looking Beyond the Horizon”



How would one simulate hundreds of spacecraft?



- **With the coming age of OneWeb, and other massive spacecraft operations proposals, how does one:**
 - Design, Model and Simulate Ground and Space Segments ?
 - **Leverage Cloud Computing & Create Service Models, such as:**
 - Spacecraft as a Service (SCaaS)
 - Flight Software as a Service (FSWaaS)
 - Ground Segment as a Service (GSaaS)
 - Auto Provision, Orchestrate & Terminate services at will



Thank you.

Any Questions?