



# Creating an Interface to View Multi-Spacecraft Swarm Telemetry

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## Distributed Spacecraft Autonomy (DSA)

<https://gameon.nasa.gov/projects/distributed-spacecraft-autonomy-dsa/>



# Agenda

About DSA

Background

Use Case

Development

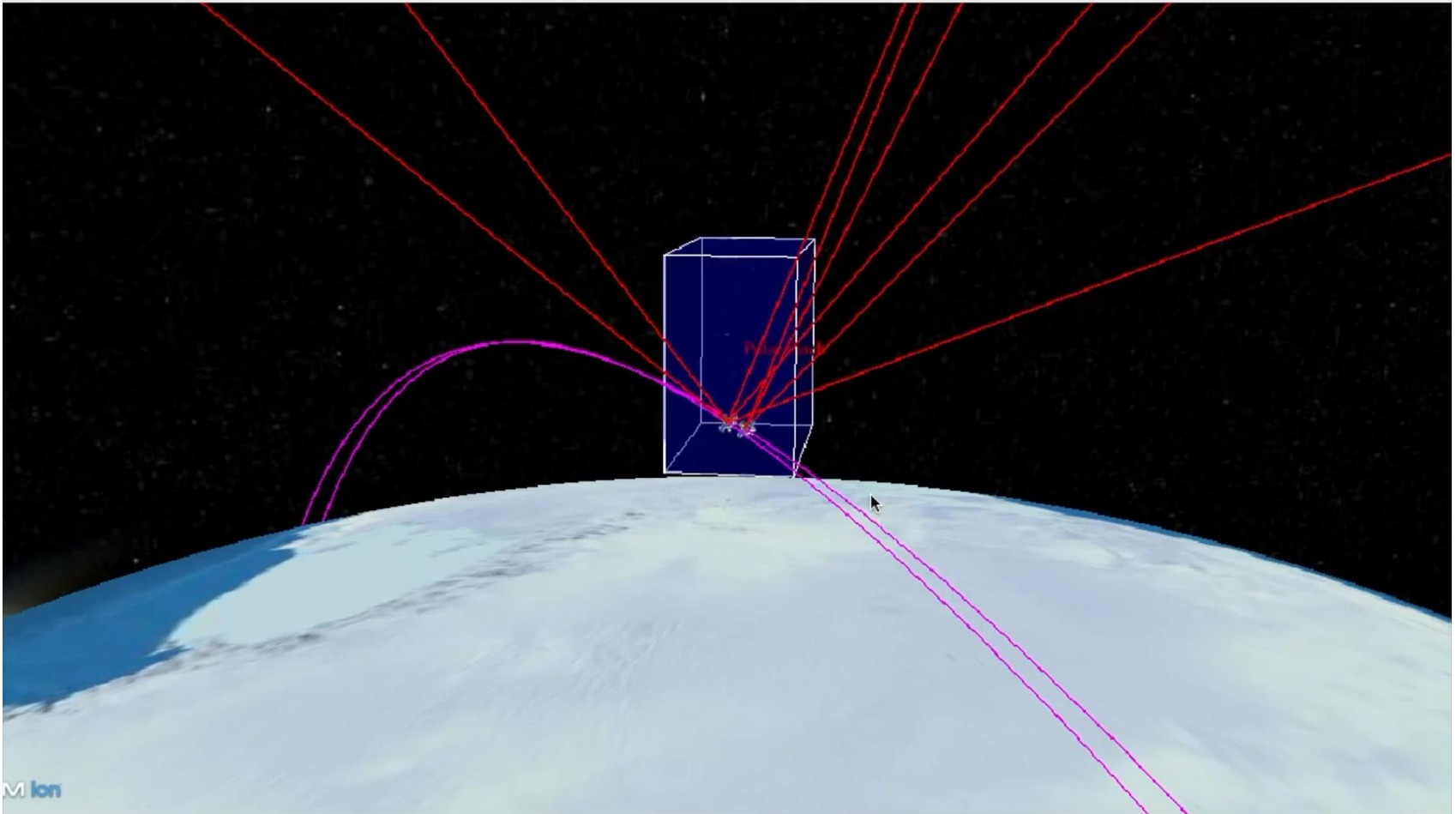


## Distributed Spacecraft Autonomy (DSA)

- Software payload on Starling which is a 4 CubeSat NASA mission to develop and advance space swarm technologies
- Goal is to advance scalable autonomy capabilities, command/control methodologies
- Includes two segments, a flight launch and a scalability study tested on ground hardware with up to 100 spacecraft



# Autonomy Demo







# Background

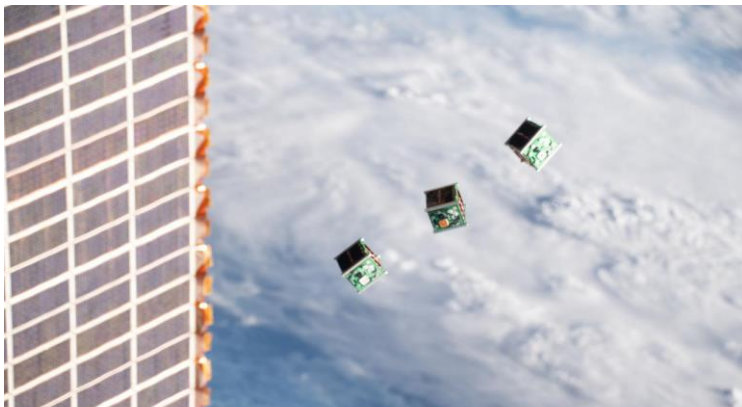


## Human-Swarm Interaction (HSI)

- Deals with interface between a human and a swarm of robots within a mission
- Part of the Ground Data Systems sub-team within DSA

## Challenges

- Informational complexity
- Reducing information overload
- Large swarm dynamics



Micro-satellite deployment mission- a constellation of three 1U CubeSats developed by Japan, Nepal and Sri Lanka

Need to understand the state of the swarm, with the ability to quickly find information of a particular satellite.





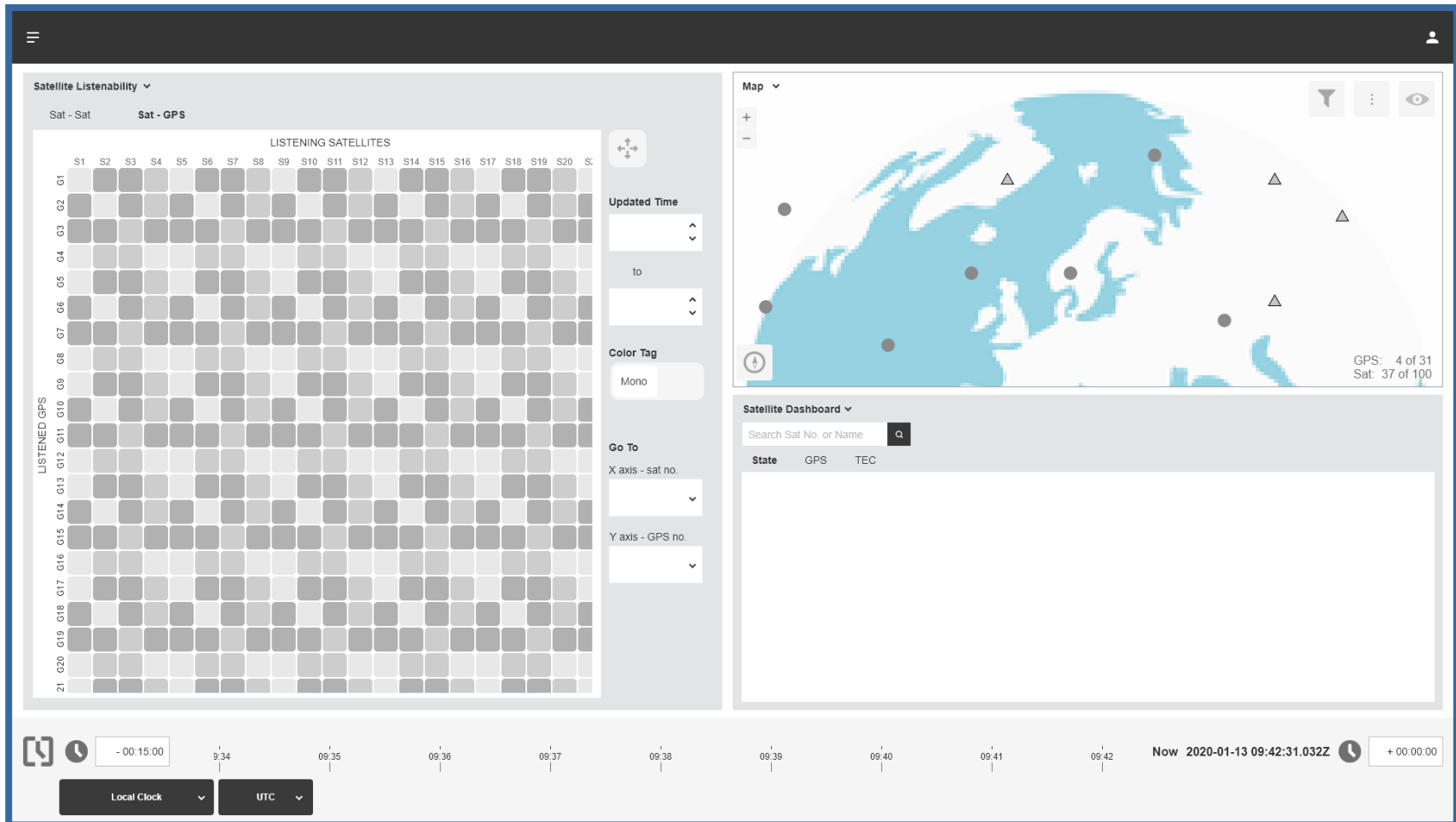
## Our Approach

- Divide HSI User Interface into several components
  - Satellite Listenability Matrix
  - Timeline
  - Map
  - Dashboard
  - Command Builder
- Determine roles associated with each component



# Interface Design

Design created by Yunkyung Kim





# Component Roles

(Supervisor, Teammate, Operator)



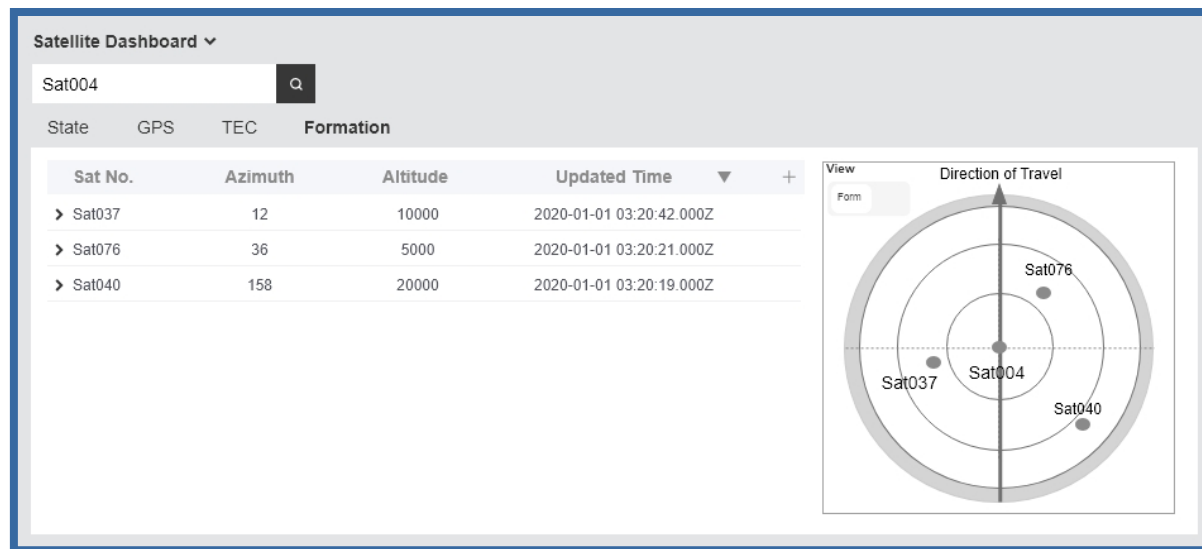
# Roles

	Supervisor	Teammate	Operator
<b>Interested In</b>	Viewing collective satellite behavior	Details of satellite behavior	Controlling satellite behavior
<b>Mission Goals</b>	Meet overall goals	Accomplish mission goals, but does not change them	Complete low-level tasks related to mission goals
<b>Examples</b>	Project Manager	Tech Lead	Operations Team





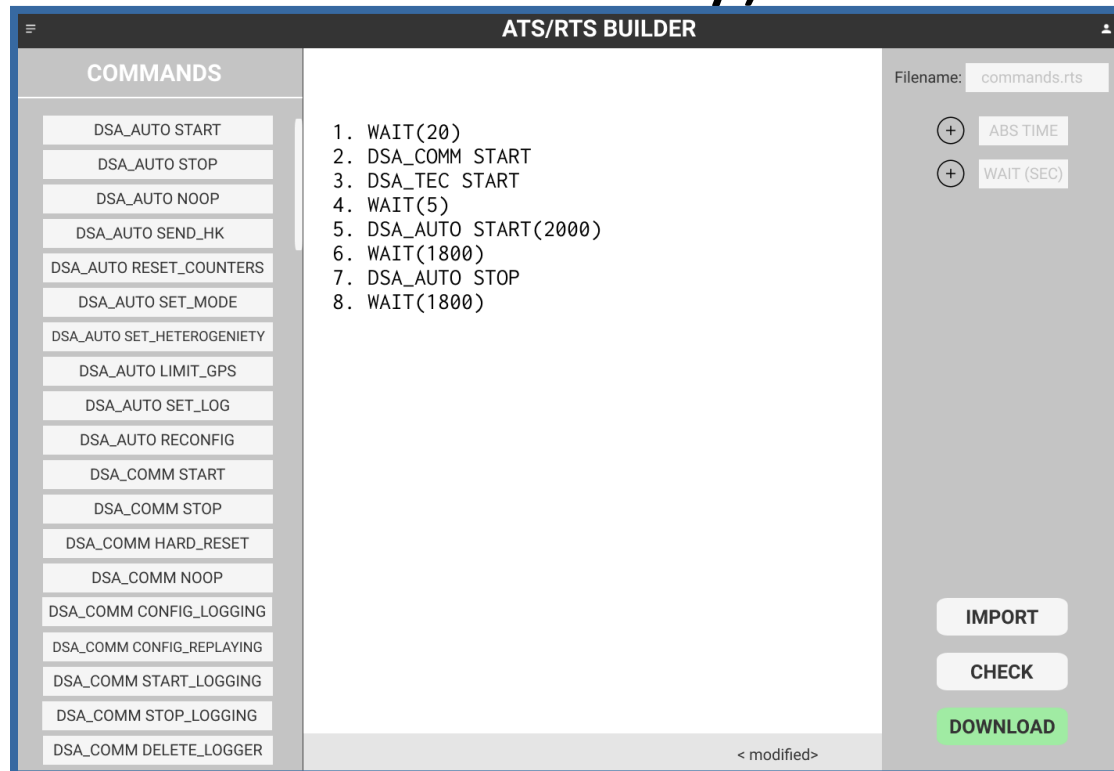
Assesses system performance against mission objectives and sets command objectives that change the collective satellite behavior to meet the overall mission goals



[illegible]



Must actively control low-level tasks on the action level (e.g. teleoperation – controlling remotely)





# Use Case





# How do we...

Interact with the spacecraft as a collective?

Display swarm autonomy?

Decrease external dependencies without reinventing the wheel?



# Analyzing Stakeholder Requirements

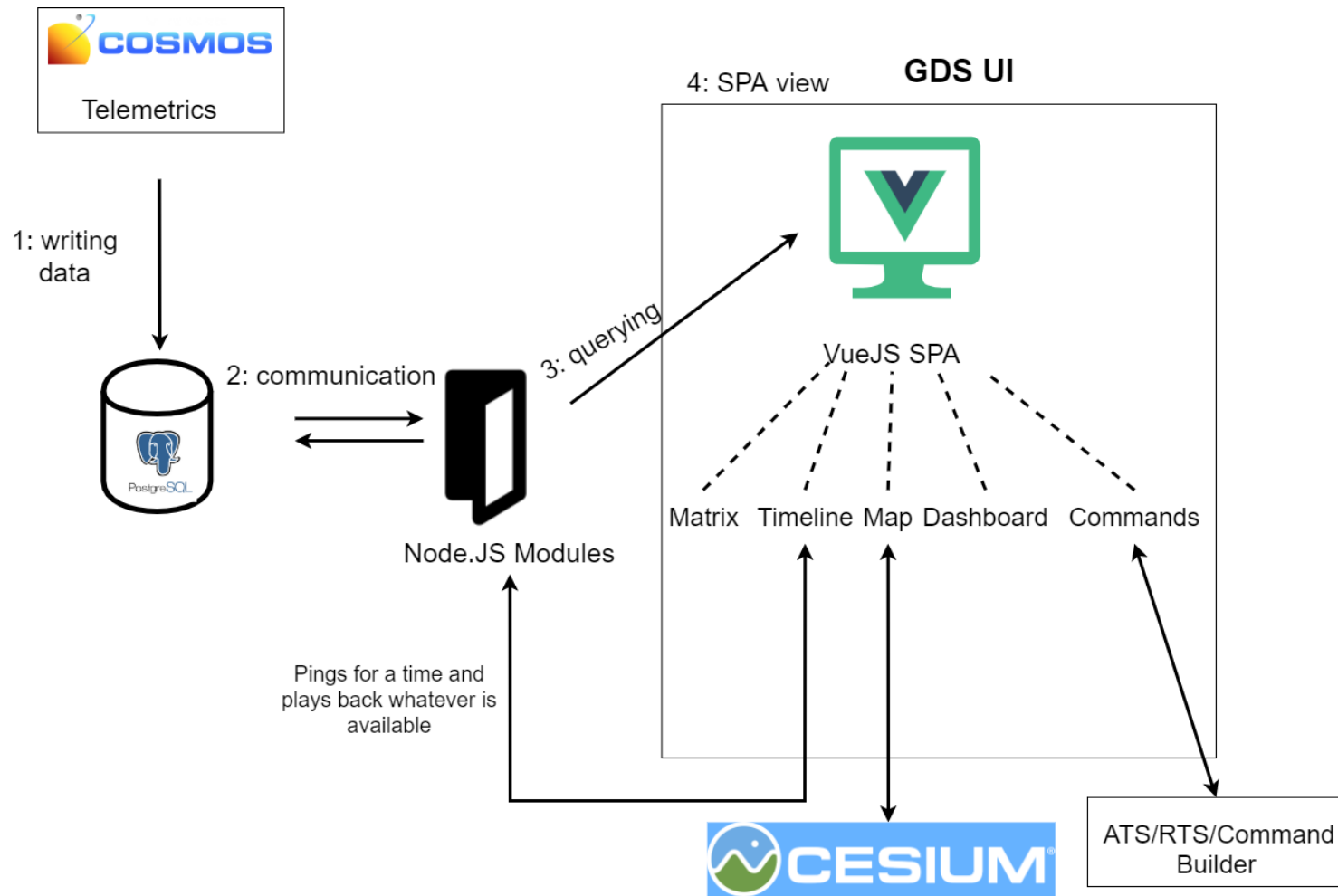
- Stakeholders each hold a different role when assessing interface
- Need to be able to view swarm status as a whole and single satellite data as needed
- Ease of access for different view modes



# Development



# Technology Stack





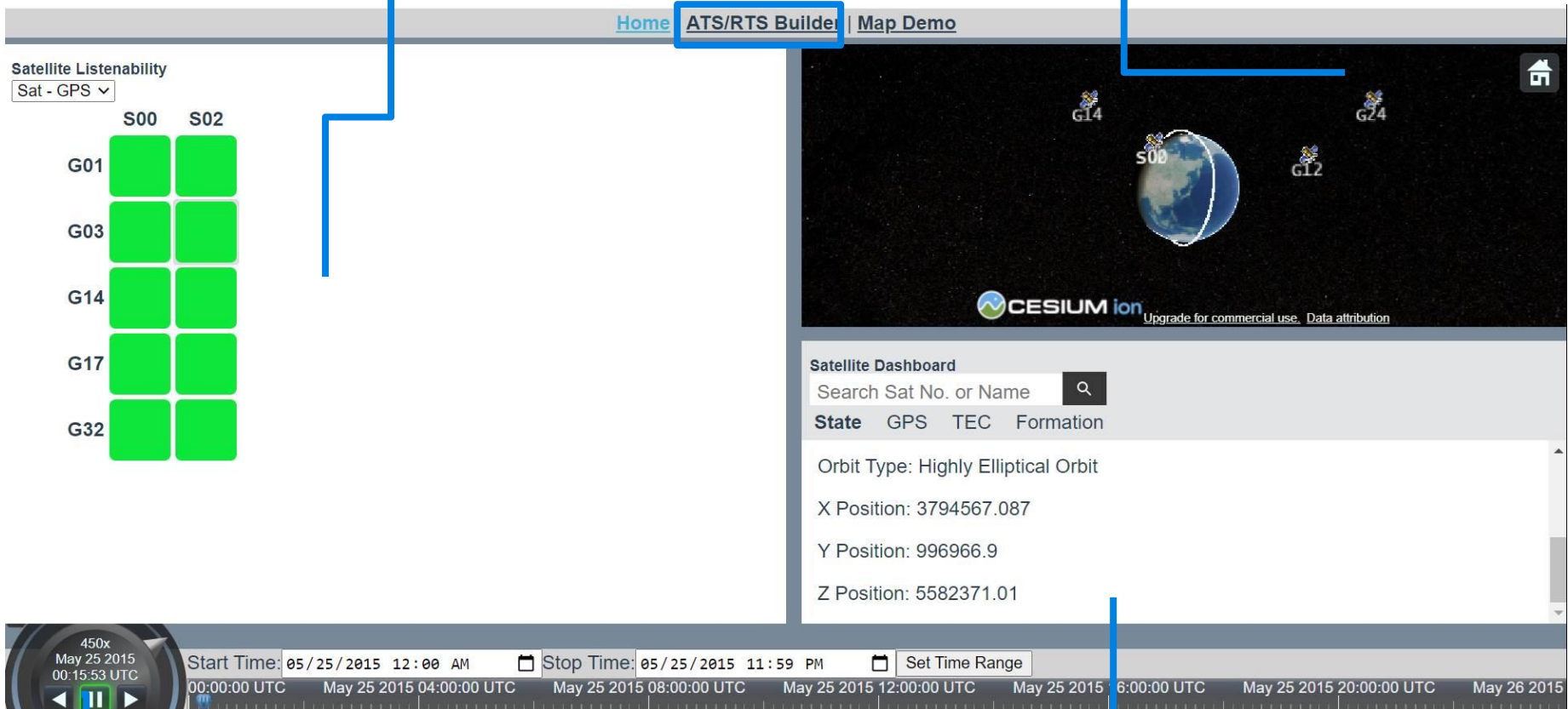


# User Interface (UI)

Listenability Matrix

Command Builder

Map



Timeline

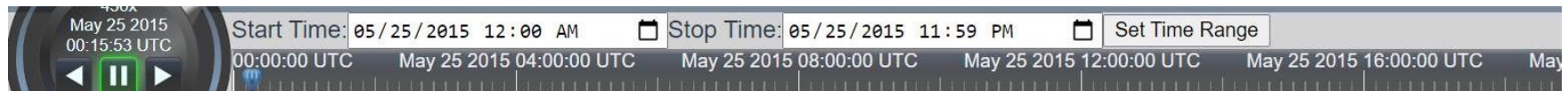
Dashboard

1/30/2021

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# Timeline



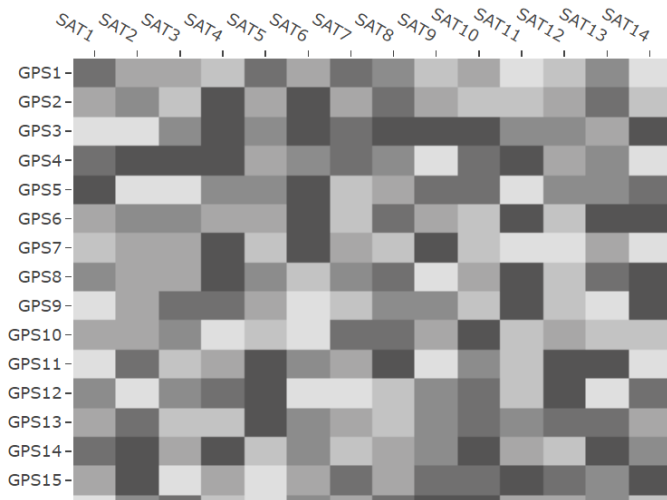
- Built using existing Cesium tools
- Controls information outputted in rest of components



# Listenability Matrix

Satellite Listenability

Sat - GPS ▾



Satellite Listenability

Sat - GPS ▾



- Shows connectivity between satellites



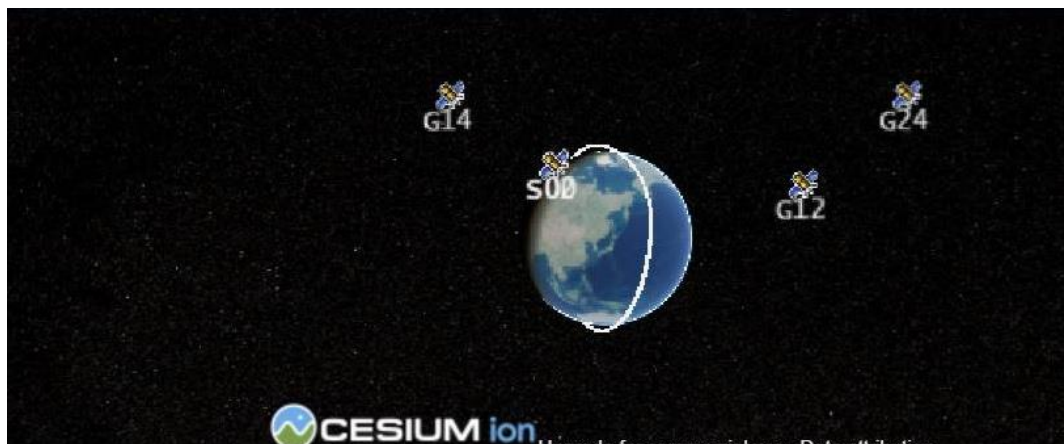
# Map







# Map





- See overall swarm positioning in reference to the Earth
- Orbit path of the satellite



# Dashboard

## Satellite Dashboard

Search Sat No. or Name



**State** GPS TEC Formation

Orbit Type: Highly Elliptical Orbit

X Position: 3794567.087

Y Position: 996966.9

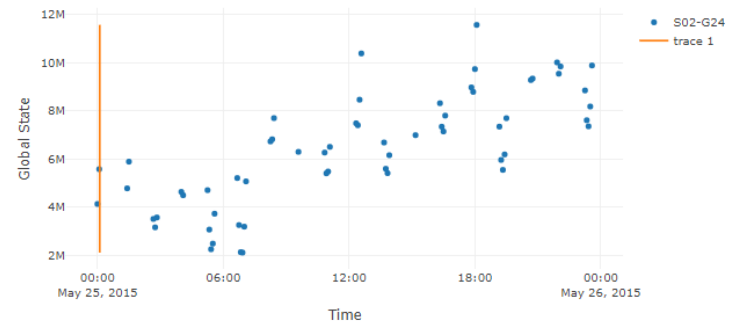
Z Position: 5582371.01

## Satellite Dashboard

S00



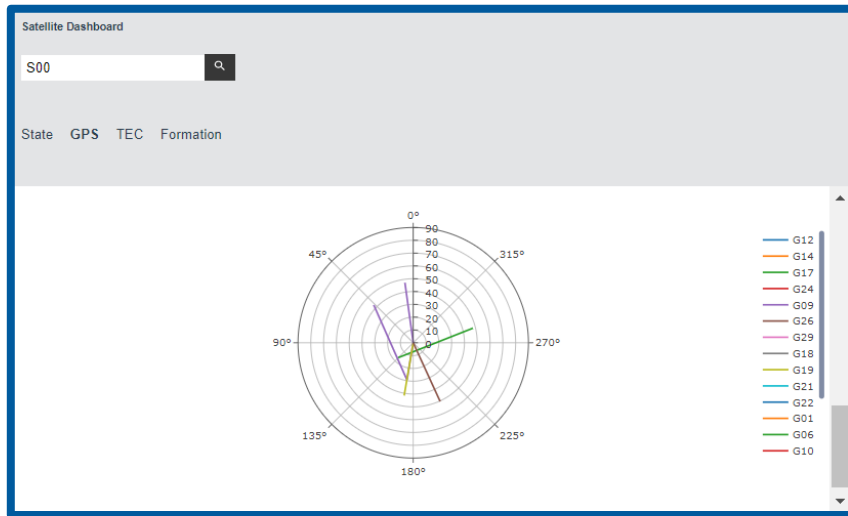
State GPS TEC Formation



- Multiple tabs for different views
- More detailed data



# Dashboard



Satellite Dashboard

S00

Q

StateGPSTECFormation

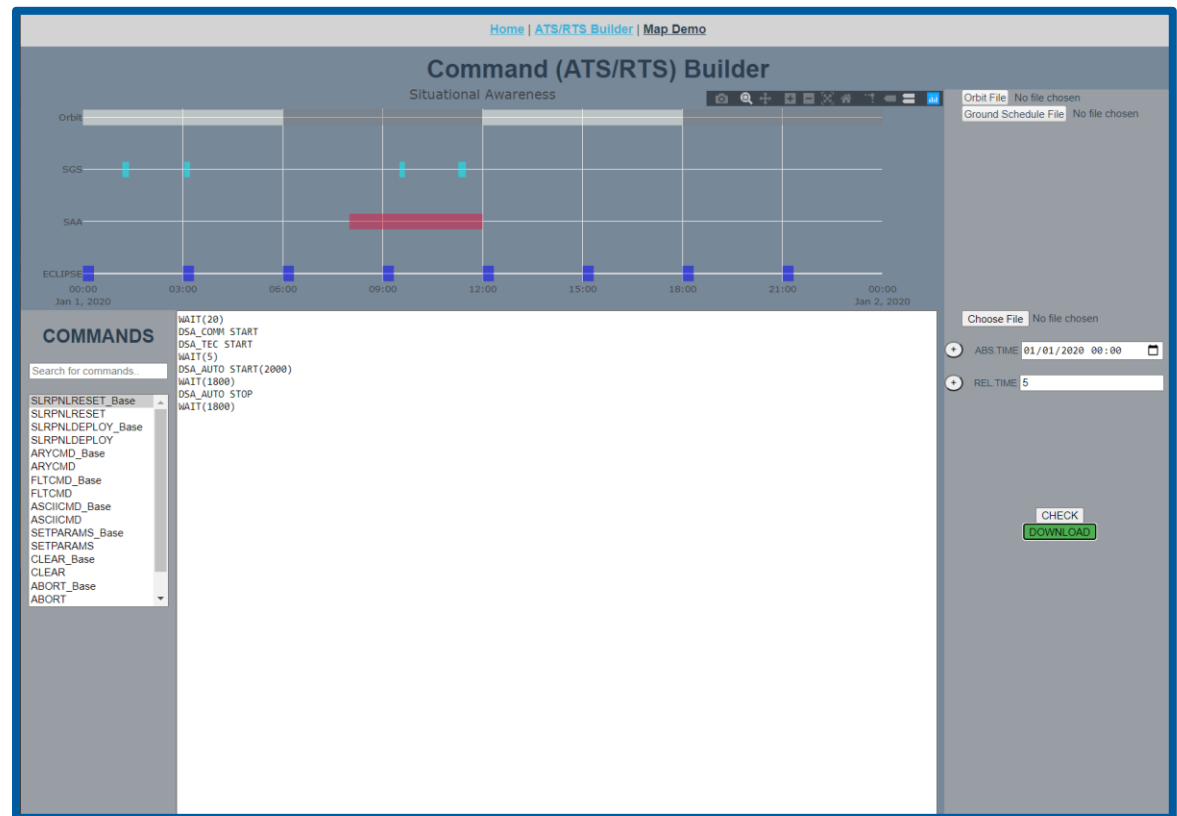
GPS No.	Azimuth	Elevation	Updated Time
	157.40685596260275	29.02331249774685	Mon May 25 2015 00:00:00 GMT-0700 (Pacific Daylight Time)
	85.17031776636871	43.28471079423851	Mon May 25 2015 00:00:00 GMT-0700 (Pacific Daylight Time)
	-76.25719977675833	47.9548444732008	Mon May 25 2015 00:00:00 GMT-0700 (Pacific Daylight Time)
	-169.9615519509003	42.63987190941006	Mon May 25 2015 00:00:00 GMT-0700 (Pacific Daylight Time)
	46.312776623067464	42.48760005599196	Mon May 25 2015 04:50:00 GMT-0700 (Pacific Daylight Time)
	136.4717870255091	42.11598999226501	Mon May 25 2015 04:50:00 GMT-0700 (Pacific Daylight Time)
	-132.06321625777412	43.71504806975825	Mon May 25 2015 04:50:00 GMT-0700 (Pacific Daylight Time)
	-70.10577280043621	48.96951924383195	Mon May 25 2015 09:40:00 GMT-0700 (Pacific Daylight Time)
	170.25025354129804	41.73720294040512	Mon May 25 2015 09:40:00 GMT-0700 (Pacific Daylight Time)
	-75.49343136003891	-3.107128846864079	Mon May 25 2015 09:40:00 GMT-0700 (Pacific Daylight Time)

- Multiple tabs for different views
- More detailed data



# Command Builder

- Build ATS/RTS commands
- Check for flight rules







# References

1. A. Kolling, P. Walker, N. Chakraborty, K. Sycara, and M. Lewis. Human interaction with robot swarms: A survey. *IEEE Transactions on Human-Machine Systems*, 46(1):9–26, Feb 2016.
2. Hussein, A.; Abbass, H. Mixed initiative systems for human-swarm interaction: Opportunities and challenges. In *Proceedings of the 2018 2nd Annual Systems Modelling Conference (SMC)*, Canberra, Australia, 4 October 2018; pp. 1–8. [Google Scholar]
3. NASA Images [www.nasa.gov](http://www.nasa.gov)