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#### Creating an Interface to View Multi-Spacecraft Swarm Telemetry



#### Presenter: Elaine Zheng Other Authors: Daniel Cellucci and Steven Hu

1/30/2021

#### Speaker

#### **Elaine Zheng**

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#### Distributed Spacecraft Autonomy (DSA)

https://gameon.nasa.gov/projects/distributed-spacecraft-autonomydsa/

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### Agenda

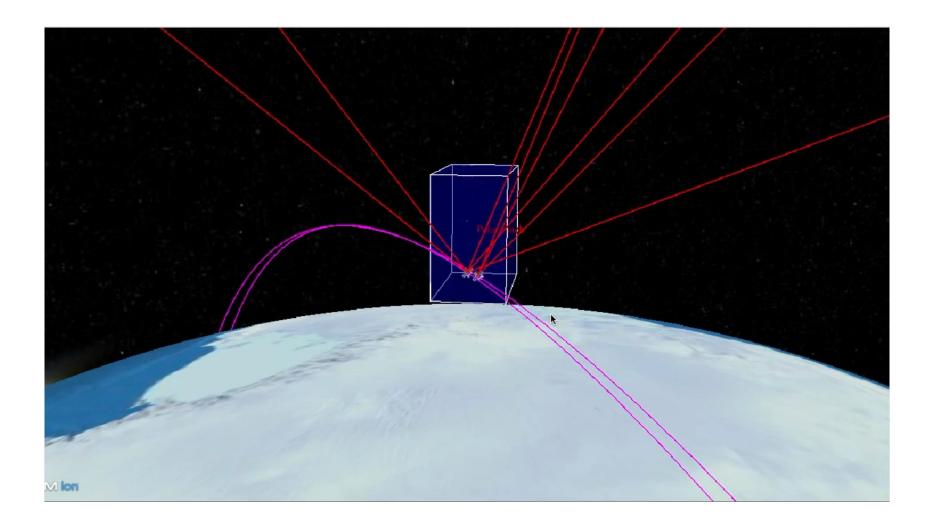
# About DSA Background Use Case Development

### About DSA

#### **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



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# Background

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#### **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

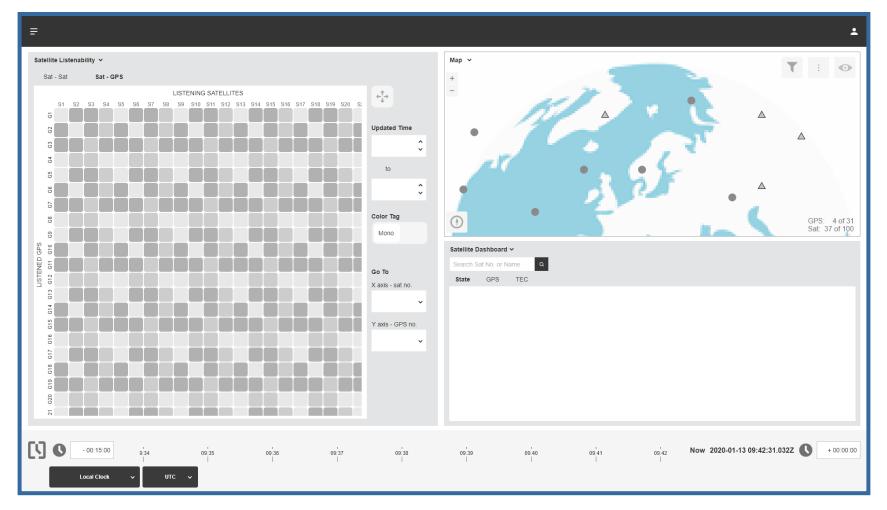
Need to understand the state of the swarm, with the ability to quickly find information of a particular satellite.

#### **Our Approach**

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

#### Interface Design

#### Design created by Yunkyung Kim





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# Component Roles

#### (Supervisor, Teammate, Operator)

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#### Roles

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

### Supervisor

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

atellite Dashboa Sat004	ard ∽				
State GPS	TEC For	mation			
Sat No.	Azimuth	Altitude	Updated Time 🛛 🔻	$^+$	View Direction of Travel
> Sat037	12	10000	2020-01-01 03:20:42.000Z		Form
> Sat076	36	5000	2020-01-01 03:20:21.000Z		
> Sat040	158	20000	2020-01-01 03:20:19.000Z		Sat076
					Sat037 Sat004 Sat040

#### Teammate

# Works with satellites in order to accomplish mission goals without explicitly altering those goals

				Updated Time
TIME	SAT 1	SAT 2	SAT 4	÷
6/24/20 2:15:01 6/24/20 2:15:01 6/24/20 2:15:01 6/24/20 2:15:01 6/24/20 2:15:01	explore: -3.081239, exploit: 19.165550 explore: -3.081239, exploit: 19.165550 explore: -3.081239, exploit: 19.165550 explore: -3.081239, exploit: 19.165550	explore: -3.081239, exploit: 19.165550 explore: -3.081239, exploit: 19.165550 explore: -3.081239, exploit: 19.165550 explore: -3.081239, exploit: 19.165550 explore: -3.081239, exploit: 19.165550	explore: -3.081239, exploi explore: -3.081239, exploi explore: -3.081239, exploi explore: -3.081239, exploi explore: -3.081239, exploi	to
6/24/20 2:15:01 6/24/20 2:15:01 6/24/20 2:15:01	explore: -3.081239, exploit: 19.165550 explore: -3.081239, exploit: 19.165550	explore: -3.081239, exploit: 19.165550 explore: -3.081239, exploit: 19.165550 explore: -3.081239, exploit: 19.165550	explore: -3.081239, exploit explore: -3.081239, exploit explore: -3.081239, exploit	
6/24/20 2:15:01 6/24/20 2:15:01 6/24/20 2:15:01 6/24/20 2:15:01 6/24/20 2:15:01	explore: -3.081239, exploit: 19.165550 explore: -3.081239, exploit: 19.165550 explore: -3.081239, exploit: 19.165550 explore: -3.081239, exploit: 19.165550	explore: -3.081239, exploit: 19.165550 explore: -3.081239, exploit: 19.165550 explore: -3.081239, exploit: 19.165550 explore: -3.081239, exploit: 19.165550 explore: -3.081239, exploit: 19.165550	explore: -3.081239, explor explore: -3.081239, explor explore: -3.081239, explor explore: -3.081239, explor explore: -3.081239, explor	Satellite 1
6/24/20 2:15:01 6/24/20 2:15:01 6/24/20 2:15:01 6/24/20 2:15:01 6/24/20 2:15:01	explore: -3.081239, exploit: 19.165550 explore: -3.081239, exploit: 19.165550 explore: -3.081239, exploit: 19.165550	explore: -3.081239, exploit: 19.165550 explore: -3.156822, explort: 25.000022 explore: -3.081239, exploit: 19.165550 explore: -3.081239, exploit: 19.165550 explore: -3.081239, exploit: 19.165550	explore: -3.081239, exploi explore: -3.156822, exploi explore: -3.081239, exploi explore: -3.081239, exploi explore: -3.081239, exploi	+ Satellite 3
6/24/20 2:15:01 6/24/20 2:15:01 6/24/20 2:15:01 6/24/20 2:15:01 6/24/20 2:15:01 6/24/20 2:15:01	explore: -3.081239, exploit: 19.165550 explore: -3.081239, exploit: 19.165550 explore: -3.081239, exploit: 19.165550 explore: -3.081239, exploit: 19.165550	explore: -3.081239, exploit: 19.165550 explore: -3.081239, exploit: 19.165550 explore: -3.081239, exploit: 19.165550 explore: -3.081239, exploit: 19.165550 explore: -3.081239, exploit: 19.165550	explore: -3.081239, explor explore: -3.081239, explor explore: -3.081239, explor explore: -3.081239, explor explore: -3.081239, explor	Satellite 4     Satellite 5
_				Color Tag
WARN	INGS			Mono
S1 and	S2 have different values for 06	5/24/2020 06:00:20		Comparison Mode
S1 and	S3 have different values for 06	5/24/2020 06:00:20		Data
S2 and	S4 have different values for 06	5/24/2020 06:00:20		
S2 and	S5 have different values for 06	6/24/2020 06:00:20		
S3 and	S4 have different values for 06	5/24/2020 06:00:20		

#### Operator

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

	ΤΕΠΙΟΙΕΙΥ				
ATS/RTS BUILDER ±					
COMMANDS		Filename: commands.rts			
DSA_AUTO START DSA_AUTO STOP DSA_AUTO NOOP DSA_AUTO SEND_HK DSA_AUTO RESET_COUNTERS DSA_AUTO SET_MODE DSA_AUTO SET_HETEROGENIETY DSA_AUTO SET_LOG DSA_AUTO SET_LOG DSA_AUTO RECONFIG DSA_COMM STOP DSA_COMM HARD_RESET DSA_COMM NOOP	1. WAIT(20) 2. DSA_COMM START 3. DSA_TEC START 4. WAIT(5) 5. DSA_AUTO START(2000) 6. WAIT(1800) 7. DSA_AUTO STOP 8. WAIT(1800)	• ABS TIME           • WAIT (SEC)			
DSA_COMM CONFIG_LOGGING		IMPORT			
DSA_COMM CONFIG_REPLAYING DSA_COMM START_LOGGING		СНЕСК			
DSA_COMM START_LOGGING					
DSA_COMM DELETE_LOGGER	< modified>	DOWNLOAD			

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#### Use Case

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#### How do we...

Interact with the spacecraft as a collective? Display swarm autonomy? Decrease external dependencies without reinventing the wheel?

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#### **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

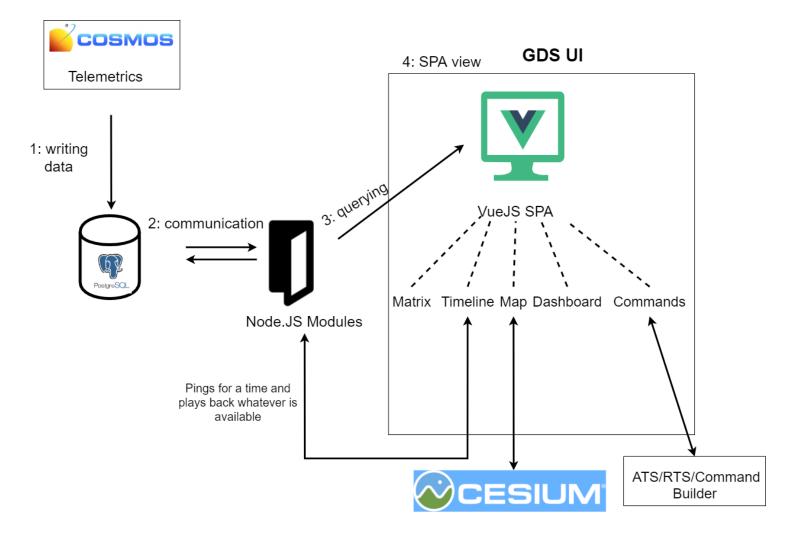


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#### Development

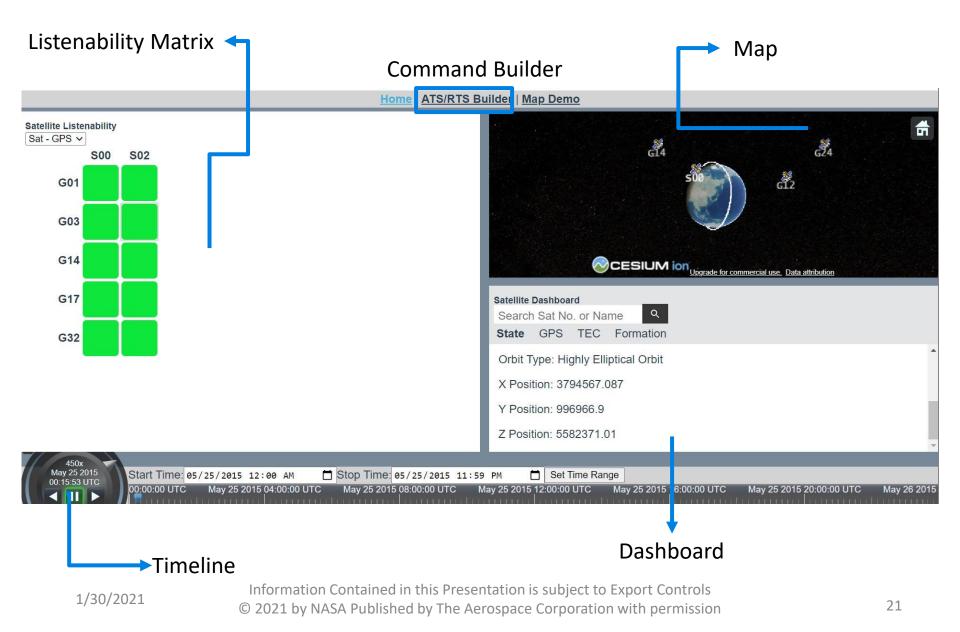
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# Technology Stack



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# User Interface (UI)

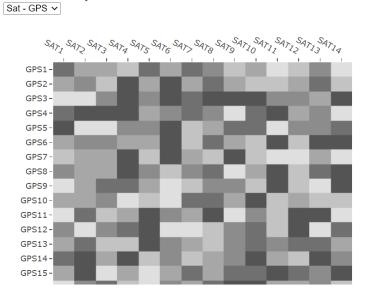


# Timeline



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

### Listenability Matrix

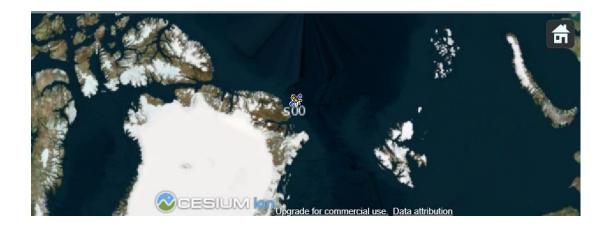




#### Shows connectivity between satellites

Satellite Listenability









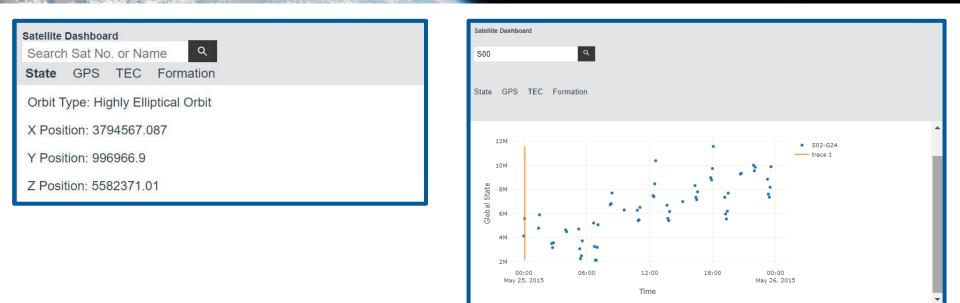
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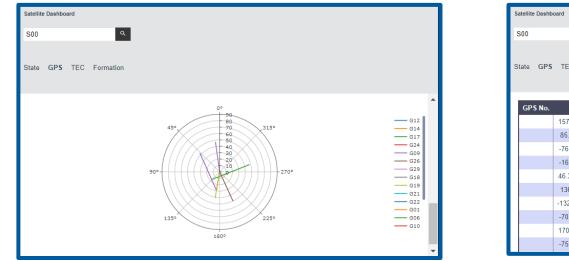
- See overall swarm positioning in reference to the Earth
- Orbit path of the satellite

# Dashboard



- Multiple tabs for different views
- More detailed data

### Dashboard

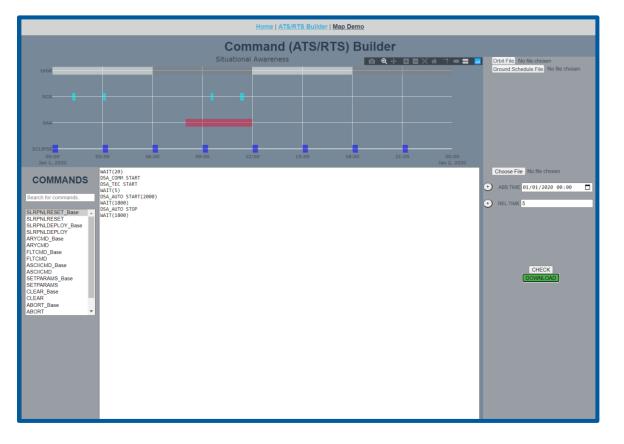


Satellite Dashbu S00 State GPS	٩		
GPS No.	Azimuth	Elevation	Updated Time
	157.40685596260275	29.02331249774685	Mon May 25 2015 00:00:00 GMT-0700 (Pacific Daylight Time)
	85.17031776636871	43.28471079423851	Mon May 25 2015 00:00:00 GMT-0700 (Pacific Daylight Time)
	-76.25719977675833	47.9548444732008	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

- 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.
- 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