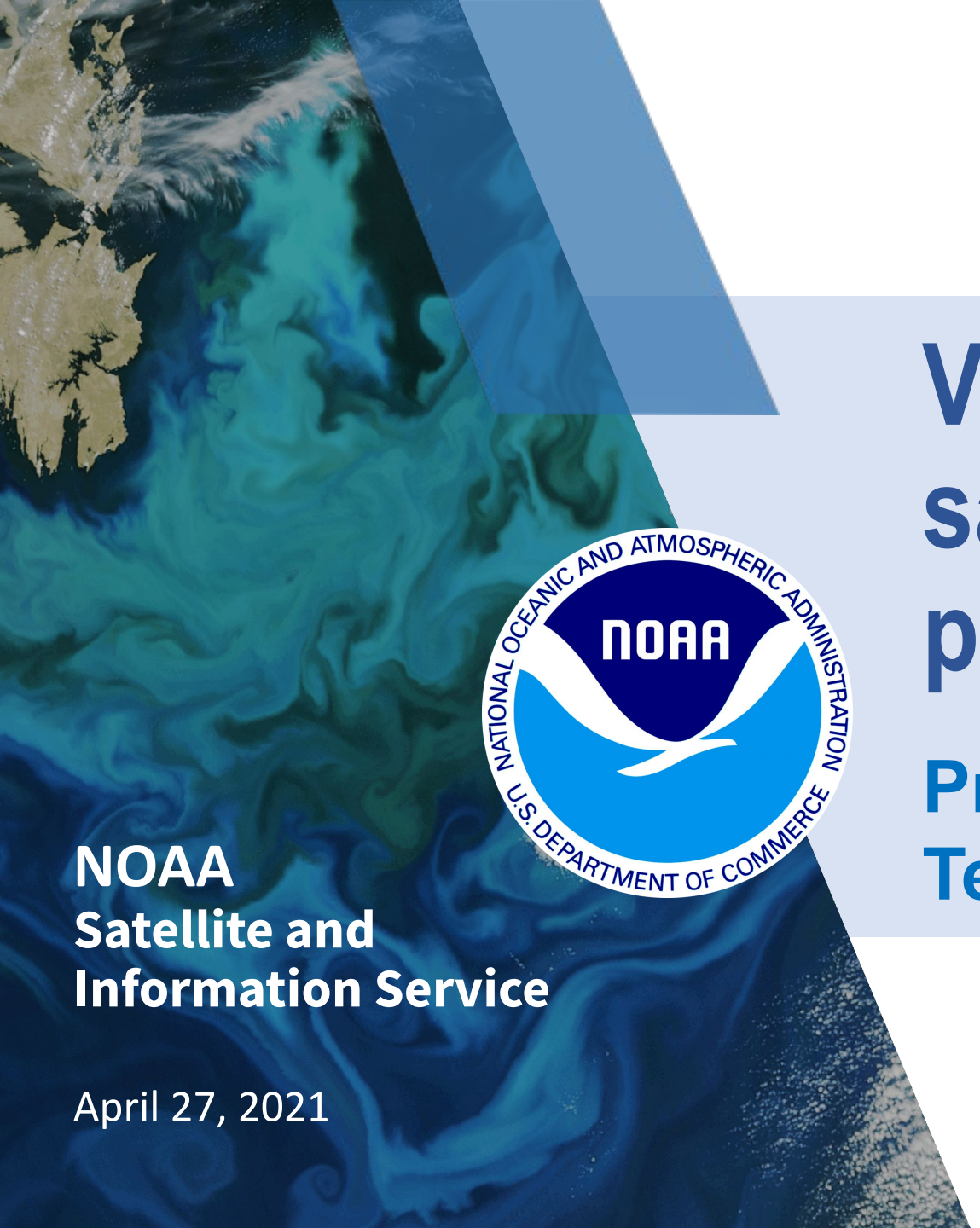


Validation of the small satellite DCS use concept project

Presented to the GOES DCS Technical Working Group

Beau Backus, JHUAPL
NOAA Satellite and Information Service

NOAA
Satellite and Information Service

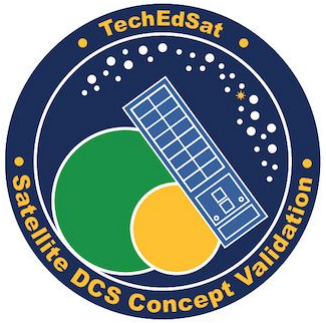
April 27, 2021

APL JOHNS HOPKINS APPLIED PHYSICS LABORATORY

Executive summary

The basic concept of the Satellite DCS Use Concept Validation project is to determine if satellites, primarily small satellites in low earth orbit, can successfully interface with the data collection system (DCS) receivers and thus provide a low-rate data (100, 300, or greater bps) service to satellite users; primarily to assist in launch, early orbit, and anomaly (LEO&A) operations or low data required observations. It is expected that the satellite use of DCS may assist in minimizing the risk of interference but will not eliminate it. Additional regulatory controls and protections will continue to be needed as well.

This project is designed to be carried on two hosting satellites. The first hosted payload was launched on 15 February 2020 and ejected from the International Space Station on 13 July 2020. This satellite focused on and was successful in demonstrating that the concept of satellites using the DCS is valid. Messages were successfully sent from the hosted payload through the DCS and received by the mission operations team (the user). The second hosted payload, planned for launch in September 2021, will focus on operational considerations, primarily can a satellite use the DCS at any time and access any subscribed DCS (i.e., EUMETSAT and NOAA).

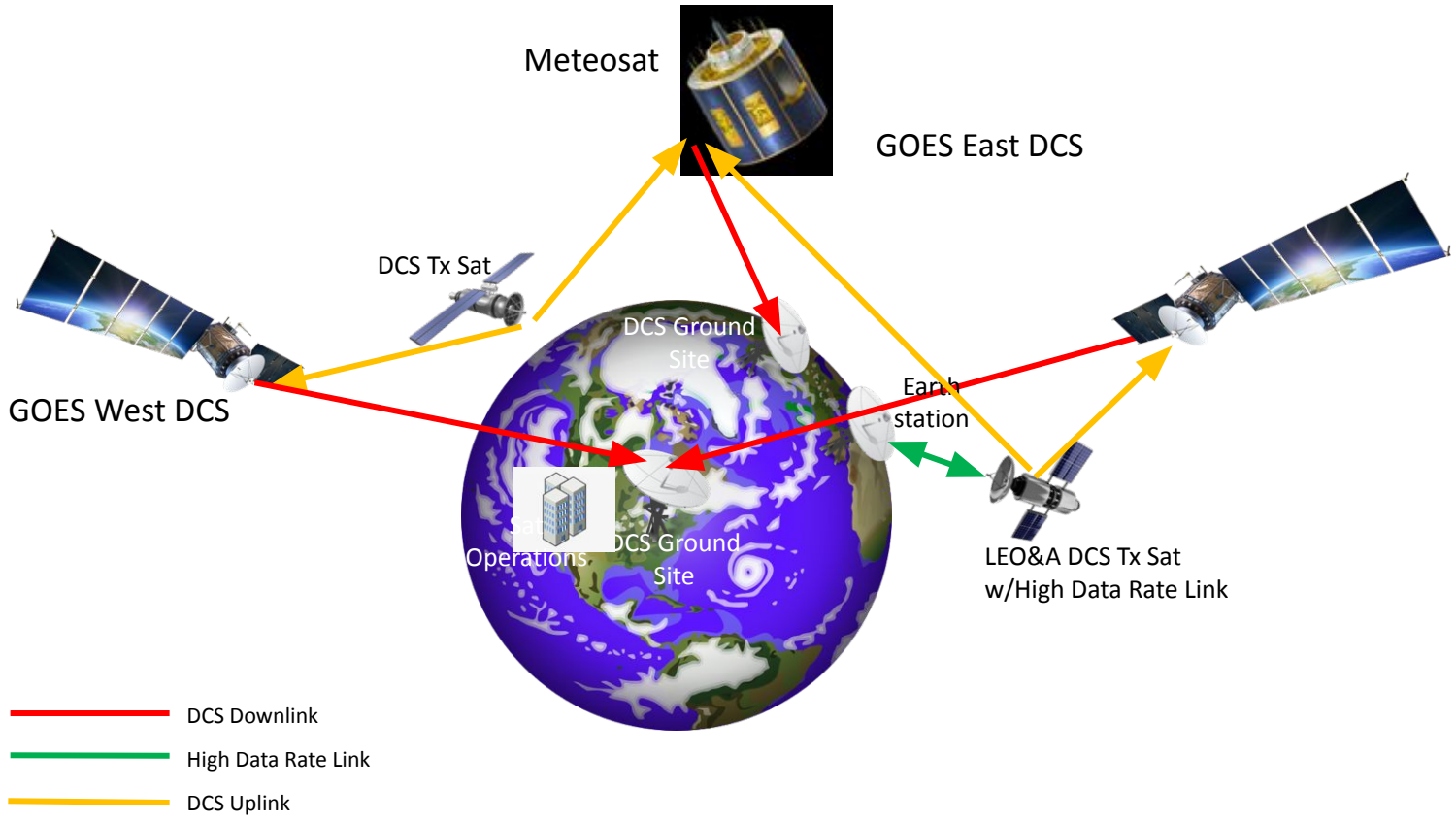


MetSats and Space Ops in 401-402 MHz

- DCS Transmitters (met sats) use the 401-402 MHz band to uplink data to the DCPR on GOES (and other DCPR equipped) satellites
- Satellites are also allocated to use this band (space-to-Earth) for space operations purposes.
  - Typically, these satellites transmit with omni antennas and so they inadvertently also radiate in direction of the DCS receiver on GOES, etc.
- Spacecraft with omni antennas increasing in numbers, resulting in a heightened need to protect DCS from RFI, which is difficult and costly to resolve.

DCS – Data Collection System
DCPR – Data Collection Platform Radio
RFI – Radio Frequency Interference

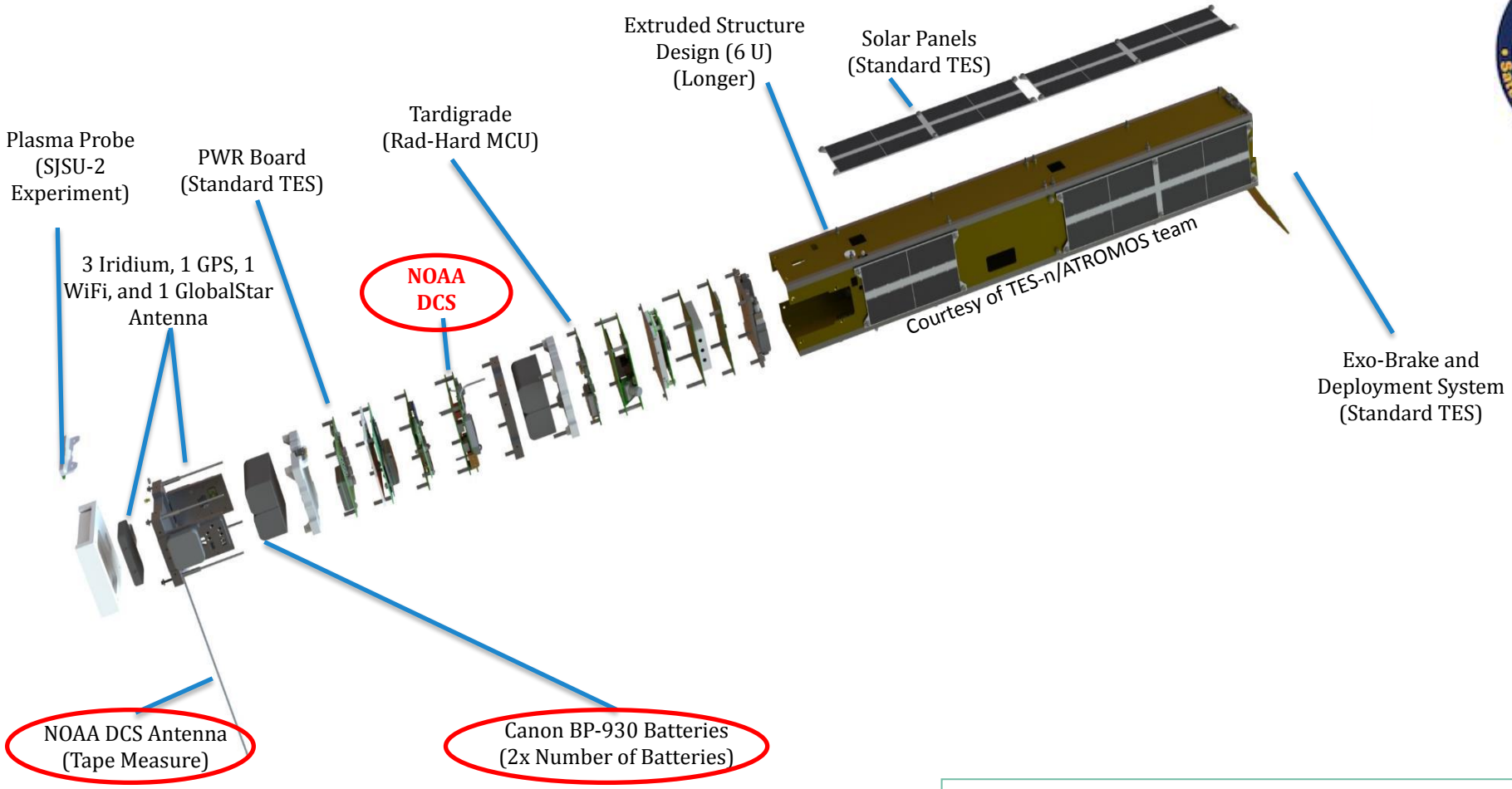
Concept: Use of DCS for Satellite Telemetry, Tracking and Small Data



TechEdSat (TES) DCS Mission

- TES-10 was a proof-of-concept using basic HW/SW for initial success.
- The experiment was conducted multiple times, with a pause between each test sequence to allow the power system to recharge
- Success criteria is data transfer from TES-10 to GOES and back through DCS channels to mission operations team
  - Success criteria accomplished on 20 Aug 2020

TechEdSat 6U Spacecraft Composition

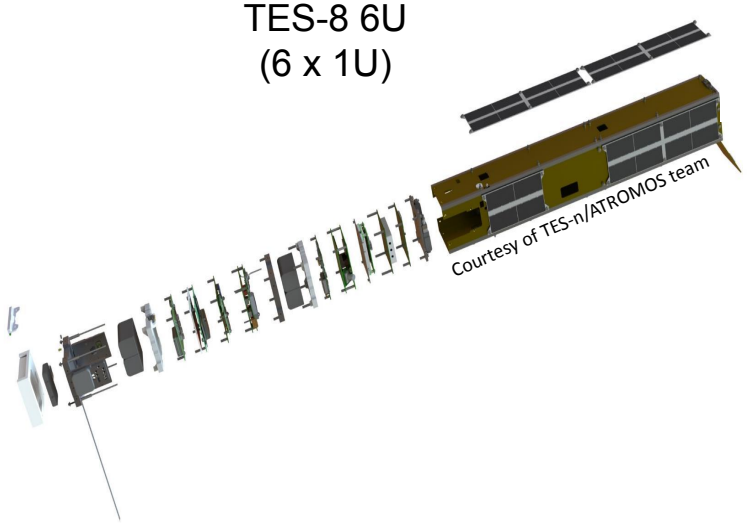


TES8/PS 8

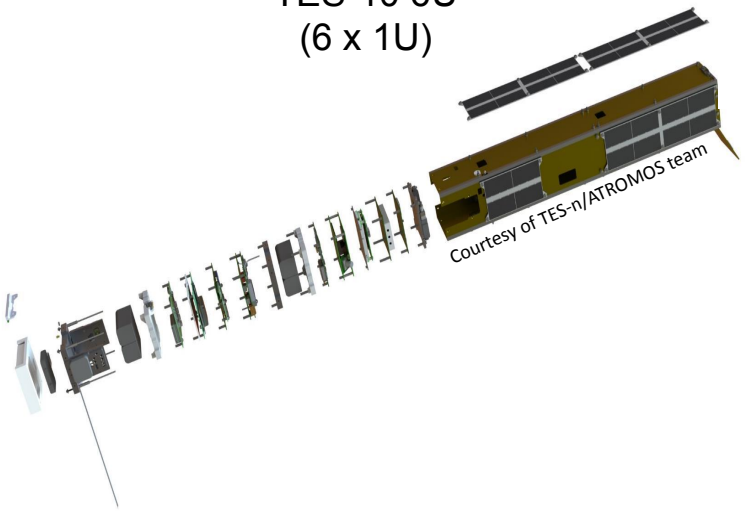
S/C – Spacecraft **SJSU** – San Jose State University
TES – TechEdSat

TechEdSat 6U Spacecraft Composition for TES-8, 10, & 11

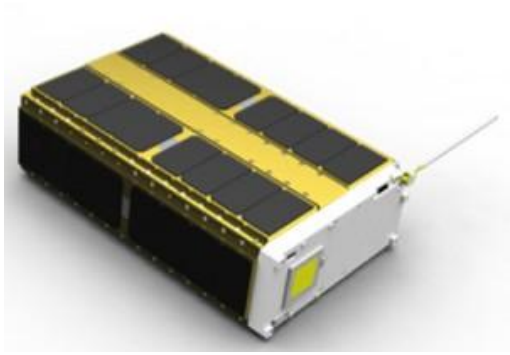
TES-8 6U
(6 x 1U)



TES-10 6U
(6 x 1U)



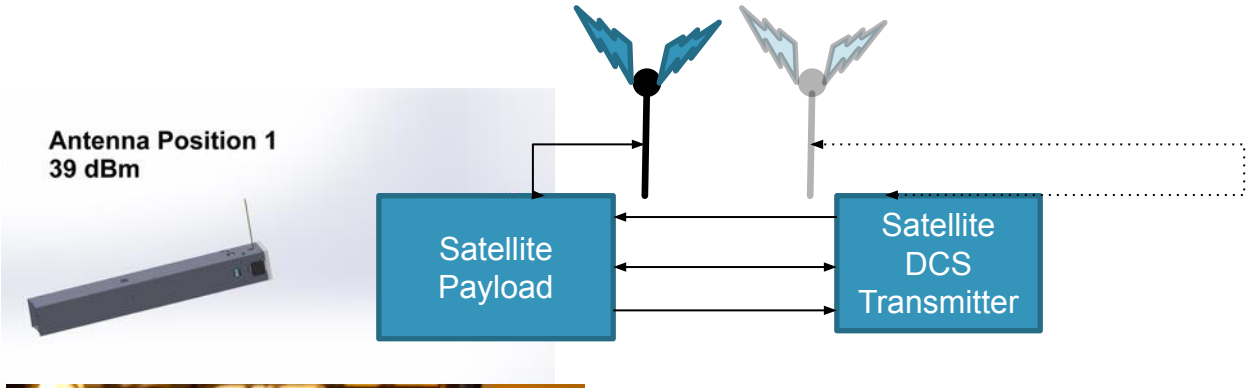
TES-11 6U
(3 x 2U)

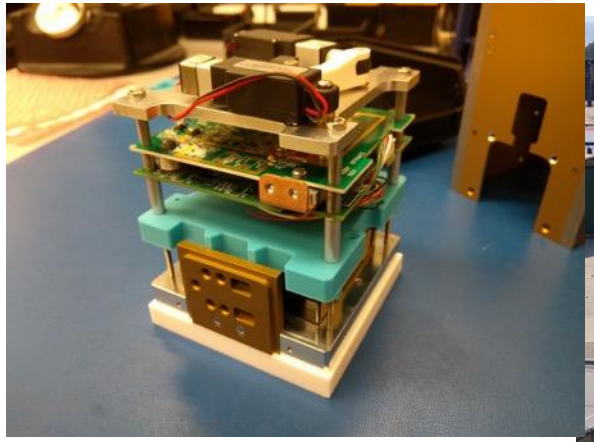


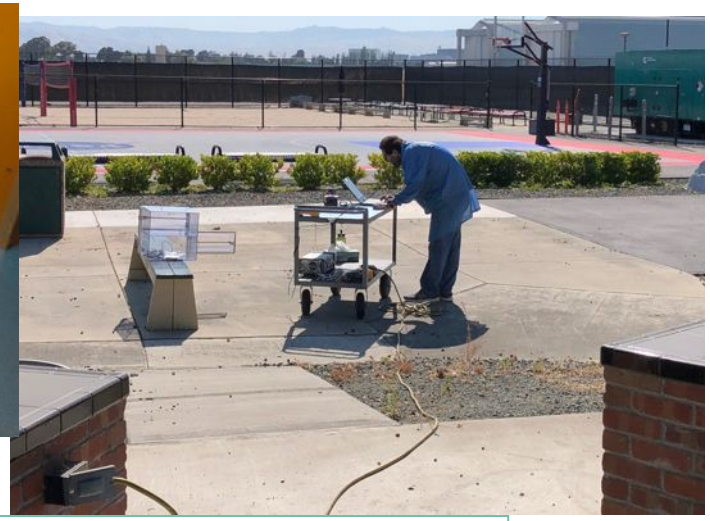
Project Team Members

- Microcom Design, Hunt Valley, MD.
  - Interested in developing and testing a DCP capability for satellites
  - Agreed to a CRADA and a CRADA extension.
  - Focus is on building and programming hosted payload boards
- NASA Ames, Mountain View, CA
  - Conducts low-cost collaborative smallsat flights to test payloads
  - Used 7600 funding vehicle. $450K to host payload on two TES.
  - Funding covers integration, prep, launch and flight support.
- NOAA with Aerospace Support
  - Project management
  - Provide Aerospace expertise in technical support, planning, and operations.

Satellite Connectivity to DCS



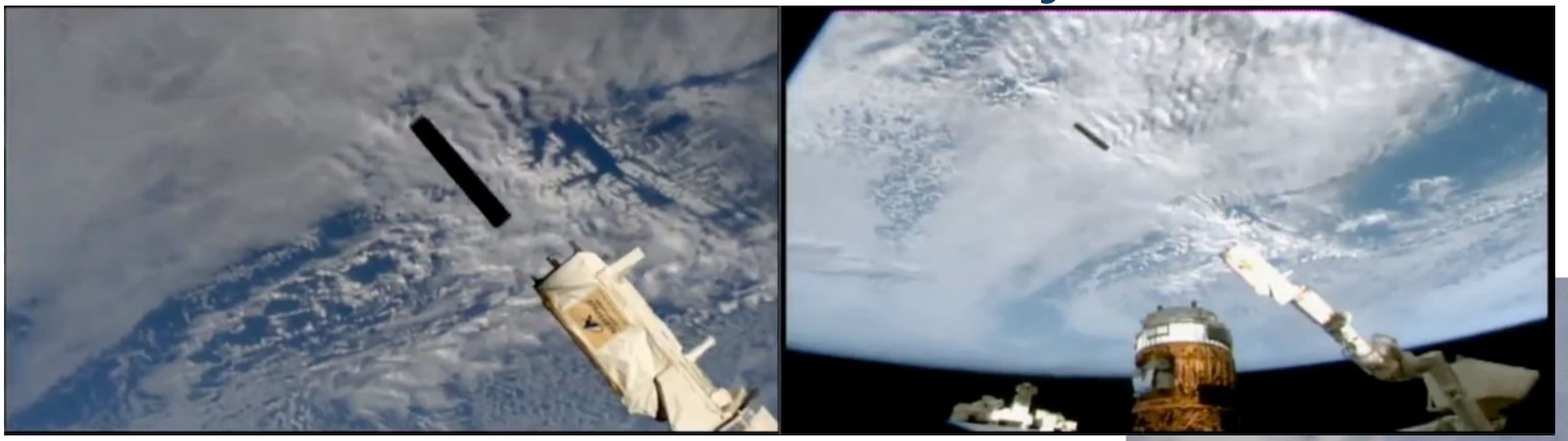




- The DCS transmitter on board the S/C will use GPS from the S/C.
- Our hosted payload will turn on for the periods allocated by DCS system
- Analysis being done to account for Doppler shift to other DCS receivers
- Interface definitions established between the S/C host and the DCS board design team
- Final testing completed and satellite transported to ISS on NG-13.

S/C – Space Craft
ISS – International Space Station
NG-13 – ISS resupply launch by Northrop Grummen

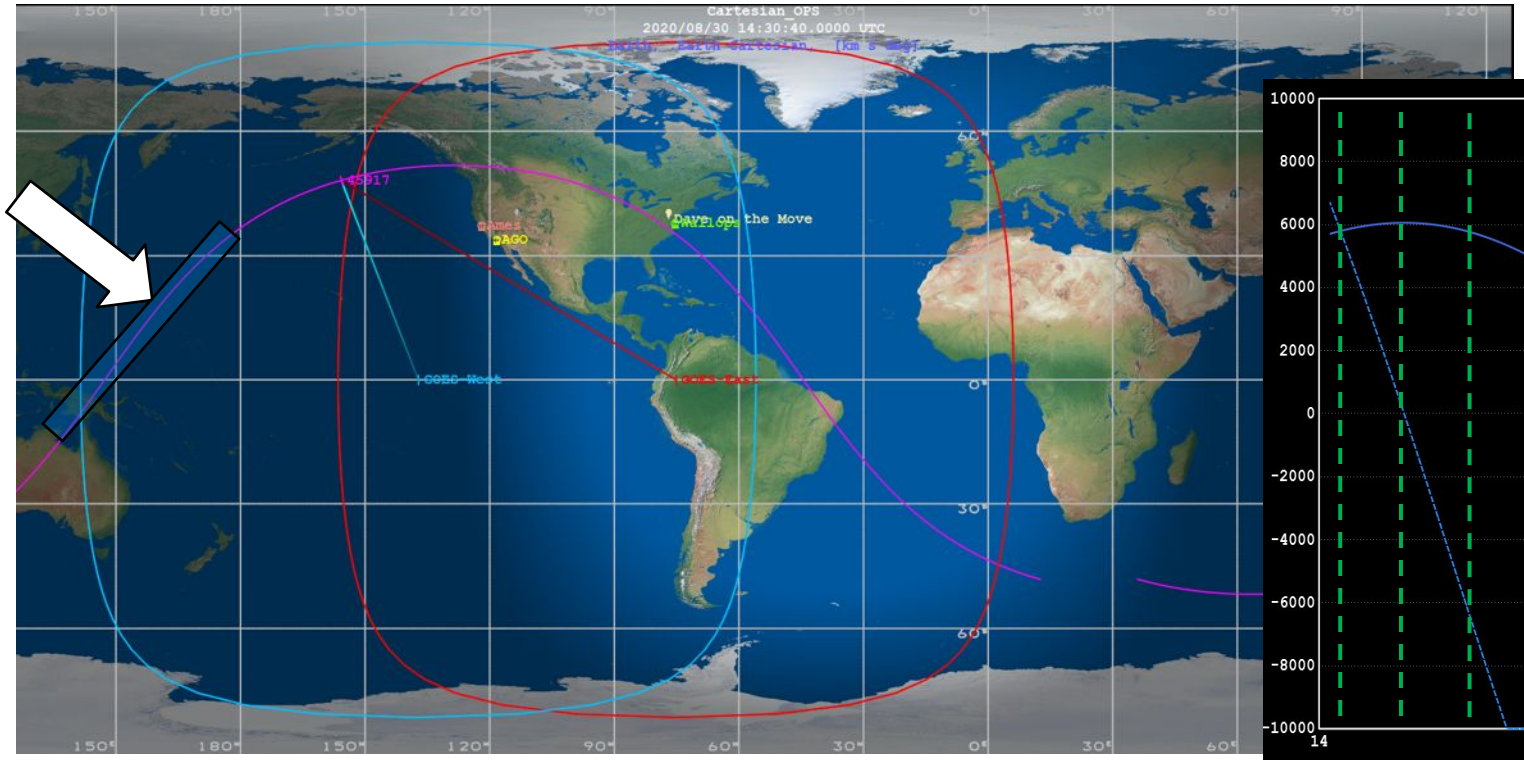
TES-10 ISS Ejection

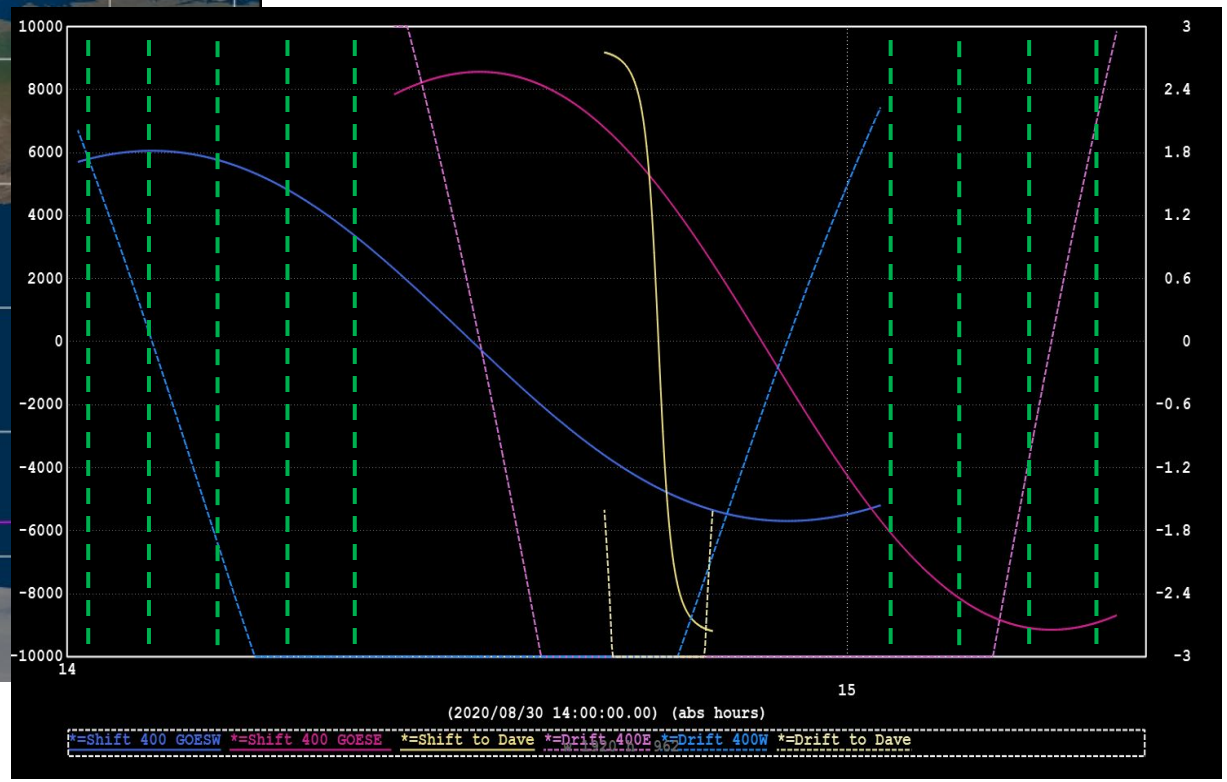


- TES-10 being ejected from the ISS on 13 July at 1655 UTC
- ISS at southern tip of South America
- Bottom right is exobrake “chute” being deployed from TES-10

Transmit Windows for GOES West and East

Sunday 30-Aug-2020; Experiment 1



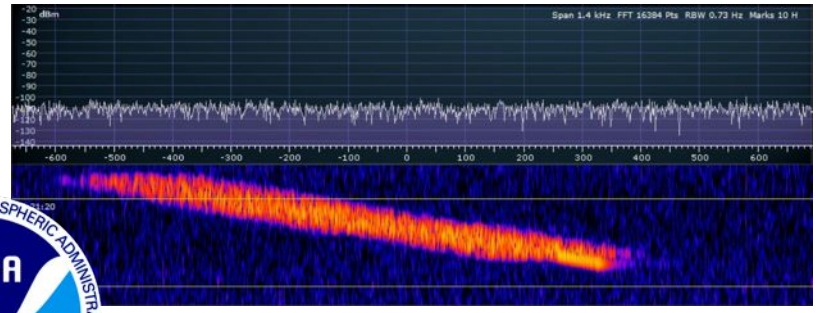


Use Doppler Correction to GOES-W Command 1:

- -33.3644,08/30/2020,14:00:50,0,0,0
- Use Doppler Tables; 1471s transmission window; 5 transmissions; Doppler correction

Satellite DCS Use Test Status

- TechEdSat-10
  - On orbit and completed validation portion of testing
    - Some engineering testing still possible
  - Satellite transmission through DCS is successful
  - Use of DCS by satellites is viable



DAMS-NT Server r1-47 [MRTA DAMS-NT EAST] [A SERVER: BACKUP] [B Server: Prime] - [Slot History [Slot42, Chan 423]]

File Setup Operations Terminal View Window Help

<< Row 1 of 2 >>

Slot	Mode	Chan	Baud	AddrCorr	AddrOrig	Carrier Time	Frame Time	End Time	Msg Dur	Len	BER	GDP	PHN	SNR	Pilot	Noise	P
42	CS2	423E	300	AE3006CC	AE3006CC	20/243 15:15:23.328	20/243 15:15:23.919	20/243 15:15:28.296	4.968	155	0E-9	84.7	5.60	18.1	46.9	19.2	
42	CS2	423E	300	230823D5	230823D5	20/243 15:10:23.323	20/243 15:10:23.915	20/243 15:10:28.292	4.969	130	8E-6	38.3	12.80	10.9	47.0	17.2	

DCP MSG DATA | DAPS/DDS | DAMS-NT | DECODED | HEX-ASCII | APPLY VIEW | FULL MSG | HIDE STATS

```
 011+7.2+10.0-6.7+8.75
Microcom GTX SmallSat Test Transmission01
Microcom GTX SmallSat Test Transmission02
Microcom GTX SmallSat Test Transmission03
AB
```

STAT_EOM	00		
BAUD RATE	300		
FRAME CHAR	R		
FREQUENCY DEVIATION	-145.2	-146.4	
AVERAGE POWER	+31.8		
NOISE POWER	+13.7		
BIT ERROR RATE	0E-9		
SIGNAL/NOISE	+18.1		
GOOD PHASES	542	640	84.7
PHASE STATS 0 DEG (+60)	+1.91	5.78	
45 DEG (-60)	+1.96	5.05	
90 DEG	-0.50	5.50	
135 DEG	-0.12	5.11	
180 DEG	-1.90	6.20	
225 DEG	-2.41	5.16	
270 DEG	+1.58	5.63	
315 DEG	+1.83	6.43	
MOD INDX/PHAS NOISE	+0.30	5.60	+2.41
MESSAGE CARRIER TIME	20/243 15:15:23.328		
MESSAGE SYNC TIME	20/243 15:15:23.803		
MESSAGE FRAME TIME	20/243 15:15:23.919		
MESSAGE END TIME	20/243 15:15:28.296		

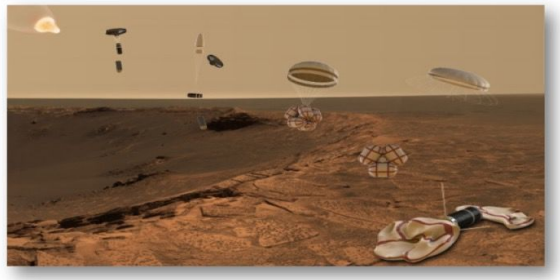
MRTA DAMS-NT EAS [CPU Usage: 1%] | MEMORY [Total: 10,485 KB] [Allocated: 8,142 KB] [Overhead: 2,343 KB] | ALLOCATIONS [Total: 166,639] [Allocs/Sec: 41,273]

WINDOWS [CPU Usage: 11%] | MEMORY [Commit Size: 19,165 KB] | UP TIME: 1 Day 17:01:48 | IP SINCE: 20/241 22:20:12 | CAGE UTC: 20/243 15:22:01

Satellite DCS Future Testing and Beyond

- TechEdSat-11
  - International DCS testing with EUMETSAT/Meteosat
  - DMOD support to Doppler shift
  - Develop an operational case for satellite use of DCS
  - Remove Doppler correction
    - Use Modified DMODs for Doppler shift
    - Use random transmit DCS channels
  - Enable command selection between 300 bd/100 bd with respective modulations
  - **Goal is to validate an operational capable use of DCS by small satellites**

- Beyond TES-11
  - Develop two-way communications (via GOES)
  - Use of higher data rates (1200/1600 baud)
  - Alternative modulation schemes for improved efficiencies
  - NASA exploring potential use of DCS-like system for lunar system monitoring
  - NASA exploring potential use of DCS-like sys surface of M



iDCS Channel Use with Satellite Use Concept

Ch #	Use	Frequency (MHz)
1	Fixed	402.0355
2	Fixed	402.0385
3	Random	402.0415
4	Random	402.0445
5	Random	402.0475
6	Random	402.0505
7	Random	402.0535
8	Random	402.0565
9	Random	402.0595
10	Fixed	402.0625
11	Fixed	402.0655

Satellite Shared Use Channels

- DCS channels are used either by fixed timing or random access
  - Random permits changing data Tx rates
- Satellites best for random access channels
  - Allows for Doppler shift
- Would fit in iDCS channels as shown
  - Both terrestrial and space users can share channels
  - Will need to relocate some users, that don't require the unique iDCS capabilities, out of the iDCS channels

Conclusion

- The 401-402 MHz band for meteorological and earth exploration satellite application continues to be under pressure for use by smallsat companies.
- Satellite access into the DCS system may alleviate some risk and further strengthen the value of protecting the system
- Issues can be resolved through engineering or policy.
  - The team viewed the obstacles encountered as challenging problems they could solve.
  - Through the success of TES-10, the team believes satellite use of the DCS is a viable option.
- The basic satellite DCS use concept is now validated and testing for a more operational capability planned for late September 2021
  - Approach can also be used by the international DCS community, expanding the availability of DCS satellite use of the international DCS bands globally.
  - Follow-on testing with EUMETSAT may confirm viability
  - NOAA and CGMS must determine if, and under what rules, this capability may be made available to smallsats.


Thank You!
TechEdSat
Satellite DCS Concept Validation