UBER In Space: USNA-18 TugSat Satellite

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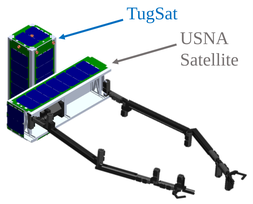
Vision

- Deliver multiple satellites to target orbits.
- Provide on-orbit ADCS (Attitude Determination and Control System) to scientific missions and partner satellites.



Example: RSat is USNA satellite for which TugSat could provide ADCS and maneuvering capabilities.

Design Goals

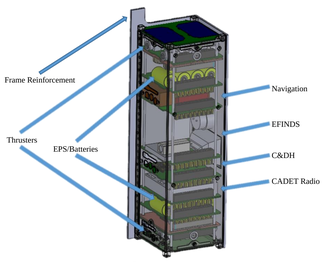
To accomplish the vision, the following technologies are needed:

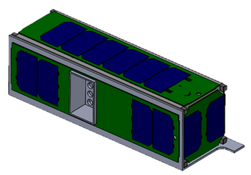
- Navigation (Relative)
  - Imaging of Target Satellite
  - Relative vector generation
- Navigation (Absolute)
- Docking/Undocking
  - Tethered on-orbit demonstration
  - On-orbit separation and docking
- Propulsion (deltaV)
- Attitude Control
  - 3-Axis Control
- Proximity Maneuvering
  - Adapting thruster (maneuvering with small deltaV)
  - Maneuver solution generation
- High Data-Rate Communication

Current TugSat System (USNA-18)
Future TugSat System Iterations

Mission Statement

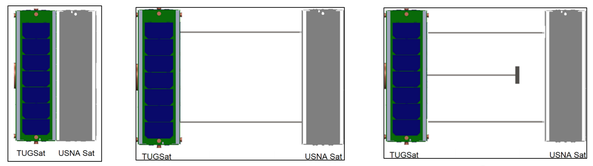
The mission of the United States Naval Academy's 10cm x 10cm x 30cm (3U) TugSat satellite system is to perform docking system demonstrations and attitude adjustments with another 3U CubeSat that lacks the means to propel itself.





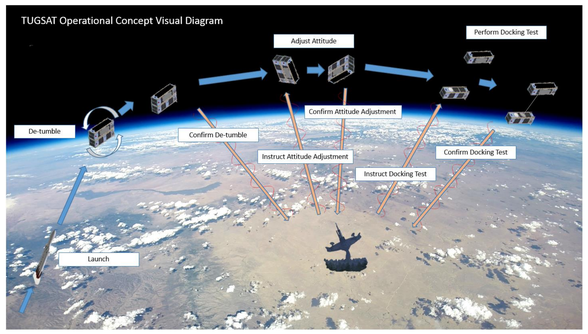
- Navigation (Relative): 3D Mapping Camera
  - Imaging of Target Satellite
  - Relative vector generation
- Docking/Undocking: EFINDS
  - Tethered on-orbit demonstration
- Attitude Control: Microthrusters, 9DOF sensor
  - 3-Axis Control
- Proximity Maneuvering: Microcathode thrusters
  - Adapting thruster (maneuvering with small deltaV)
- High Data-Rate Communication: Cadet/MC3

Concept of Operations



1. TugSat and a host USNA Satellite launch into orbit together.
2. TugSat de-tumbles and adjusts the attitude of the system, and then the satellites separate. They are held together by guide wires.
3. TugSat extends it's docking system (EFINDS) to mate with the host satellite.

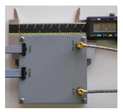
OV-1

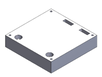


Subsystems:

Communications

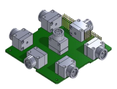
- The CADET radio utilizes a UHF uplink and S-Band downlink to provide a high data rate to support the mission while remaining compatible with the USNA ground station.
  - Transmitter Mode Power = 16 W
  - Receive Mode Power = 0.7 W
- Antenna design for TugSat will be two 2.2 GHz monopole antennas, placed 90 degrees out of phase for the S-Band downlink:
  - Transmitting is more important to the mission
  - Setup allows TugSat to have almost omnidirectional transmissions.
- There has been a successful test of the preliminary downlink capability of CADET radio.



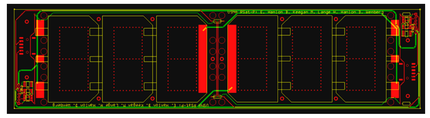


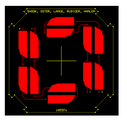
Attitude Control System

- TugSat (USNA-18) will utilize 14 Magnetically-Enhanced Micro-Cathode Vacuum Arc (μCat) Thrusters for its attitude control system.
- These experimental thrusters were developed in partnership with George Washington University to allow CubeSats to have fine attitude control using electric thrust.
- The thrusters have a high Isp (3000s) and low thrust (1μN.)
- The thrust output can be throttled by changing the number of arcs/second from 1 Hz up to 50 Hz. The required power goes up proportionally to rate of fire.
- The 14 thrusters are arranged to provide 6-DOF control over the satellite. There are 8 thrusters on the X-faces, 4 on the Y-faces, and 2 on the Z-faces spread over two identical boards.



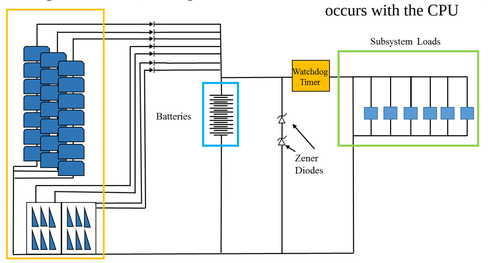
Electrical Power System



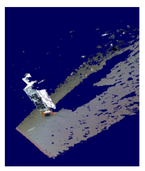


Electrical Power System Specifications	
Capacity	120 A-Hr
Average Power Generation/Orbit	3.85W
Average Power Consumption/Orbit	2.43W
System Duration in Eclipse (Normal Mode)	100 Hr

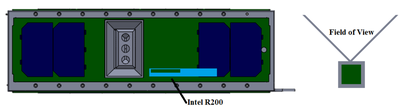
- Each 10cm x 34cm face contains 6 Spectrolab UTJ Solar Panels in series
- Each 10cm x 10cm face contains 12 TrisolX Solar Wing Solar Panels, 2 strings of 6 in series
- 10 1.2V NiCd Cells provide 12V for the system during eclipse
- A watchdog timer resets the power to the whole spacecraft if a problem occurs with the CPU



Navigation

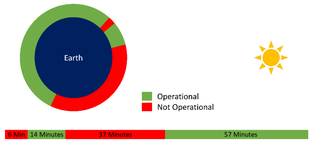


Practical Testing



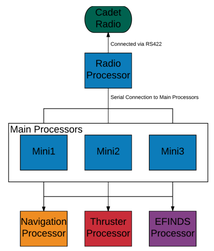
- The R200 is intended to serve as the primary rendezvous sensor for a TugSat mission. It provides 3D depth information for objects located in the vicinity of TugSat.
- A depth stream contains depth information for every pixel.
- The depth calculation is completed using stereoscopic vision.

- A variety of representative objects in a space like environment were imaged to establish what conditions the camera functioned in.
- The practical analysis was used to determine what orbit environment the camera functioned.



Theoretical Analysis Result

C&DH

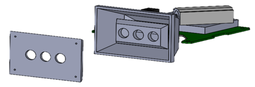


- The command and data handling system is a distributed C&DH system. Three processors was selected to allow for eventual expansion to a "voting" system.
- No single processor on the spacecraft is in control of the whole spacecraft.
- Allows for resilient operations, as every main processor has a direct connection to the radio.
- Any processor on the spacecraft can assume operational control of all subsystems.
- Built around three ATMEL 328P processors, shown each directly connected to the radio bus via "multi-drop" serial connection.

EFINDS

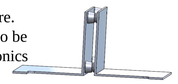
EFINDS Specifications	
Tether Length	60 cm
Motor	Faulhaber AM0820-a
Material	UV resistant Plastic

- EFINDS (Electromagnetic Ferromagnetic Integrated Docking System) is a prototype docking system intended to allow TugSat to test the concept of docking small satellites in space.
- Consists of a magnetic assembly extended via a nitinol tether, allowing docking to initiate without precise attitude control.
- Magnetic assembly contains permanent magnets oriented in opposing directions, lowering the magnetic torque on TugSat.



Structure

- TugSat utilizes a solid Pumpkin 3U chassis, with several ports drilled out for thrusters, EFINDS and other hardware.
- In order to launch with a partner satellite, TugSat will also be equipped with a frame reinforcement and an NEA electronics HDRM(hold down and release mechanism) which will secure the two craft together during launch.



Conclusion

The systems implemented in the TugSat Capstone fulfill the requirements laid out for the current version. The 14 Magnetically Enhanced Micro-Cathode Vacuum Arc Thrusters (MEMVA) provide attitude control, while EFINDS and Navigation subsystems allow TugSat to perform the current mission requirements of gathering and providing information on tethered docking and close proximity imaging of cubesats. The EPS and communications subsystems provide a backbone for future projects that will test and employ modified or improved docking, navigation, and control subsystems.

USNA-18 Design Goals	
Imaging of Target Satellite	✓
Relative vector generation	✓
Tethered on-orbit demonstration	✓
3-Axis Control	✓
Adapting thruster (maneuvering with small deltaV)	✓
High Data-Rate Communication	✓

References

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Acknowledgements

TUGSAT

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