Guidance, Navigation, and Control Analysis Activities at MSFC
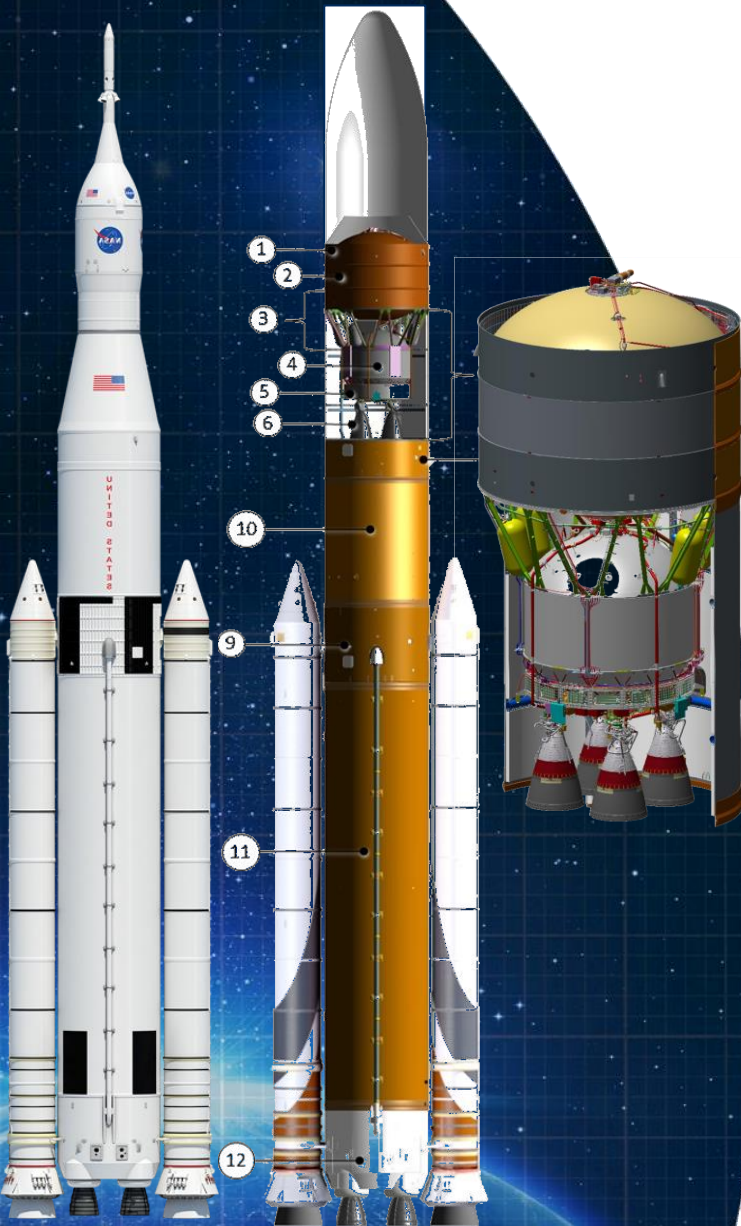
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January 24, 2017

MARSHALL
SPACE FLIGHT CENTER

# Human Exploration Program

- **SLS EM-1**
  - Flight delivery of GN&C model to Flight Software
    - Feature-locked, fixes only for any issues identified during testing
    - Hardware-in-the-Loop testing planned
  - Supporting design updates for ULA ICPS to include GPS
  - Launch window performance assessment
  - RINU gyrocompass twist-and-sway test (spring 2017) at MSFC's Contact Dynamics Simulation Lab
  - VAC1 Re-integration (V&V) Cycle
    - Sensor model validation planned for early next year
    - Moving toward DCR in 2017 (verifications meet requirements)
  - RINU and RGA units in qualification testing
    - Flight units going through acceptance testing
  - Development of Best Estimated Trajectory reconstruction algorithms
  - Nonlinear Slosh Assessment (Core Stage and EUS)
    - Ongoing trade to meet control stability with minimal baffle mass
- **SLS EM-2/EUS** (Exploration Upper Stage)
  - EUS PDR December 2016 (board mid-January 2017)
  - DAC-1 GNC Design complete (PDR-level) for integrated vehicle
    - Maturing towards CDR over 2017
  - PEG vs. OPGUID in-space guidance algorithm study
  - Development of GPS/IMU integration algorithms
  - RCS sizing and assessment
  - TVC design verification and assessment
  - RINU & RGA placement studies
- **Commercial Crew**
  - Insight/oversight of ascent & in-space GN&C, AR&D
- **NESC Support**
  - Assessment of AAC in support of flight on EM-1
  - Flexible Body Dynamics of Core Stage/EM-1
    - Reviewing uncertainty assumptions
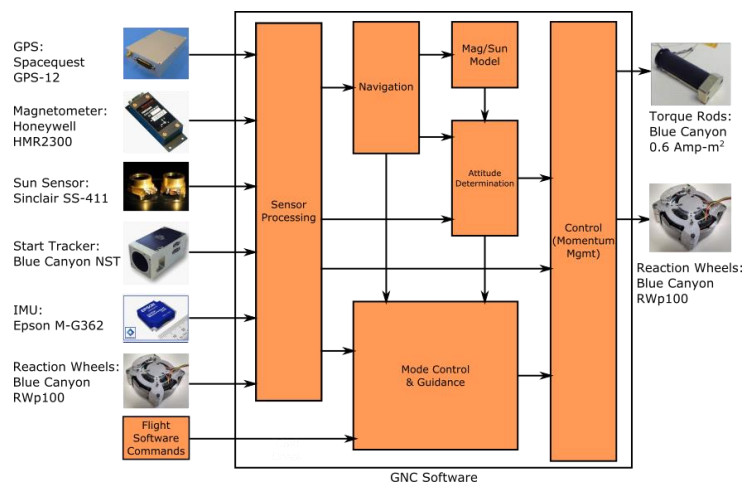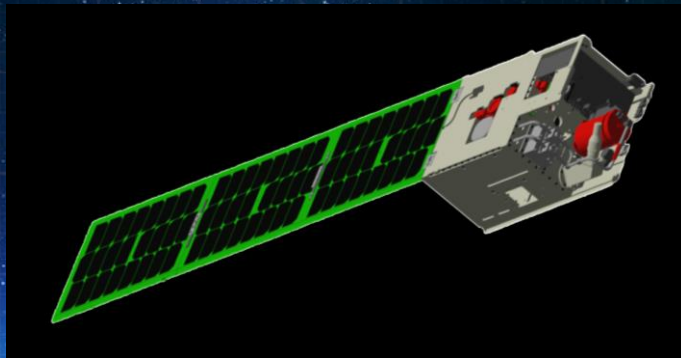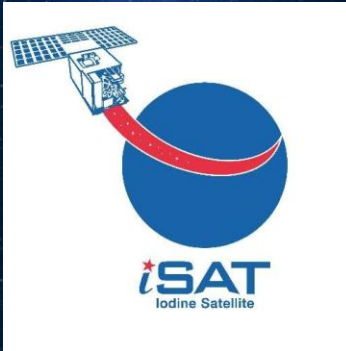   - Late modal test leaves little time for re-design

NEA(Near Earth Asteroid) Scout

- 86 m^2 solar sail deployed on 6U cubesat
- To be deployed from SLS EM-1 mission
- G&C work moved from JPL to MSFC in Oct 2015
- Blue Canyon star tracker, reaction wheels, sun sensors
- VACCO cold gas prop system for initial rate damping & early maneuvers
- Sensonor IMU
- Sail mass translation stage for momentum mgt. after sail deployment
- Primary Responsibilities
  - G&C Flight Software
  - Generated using Matlab Simulink/Autocode
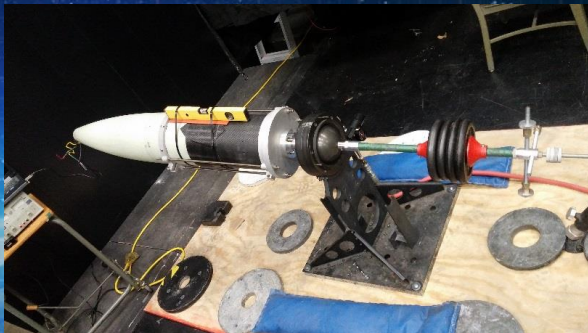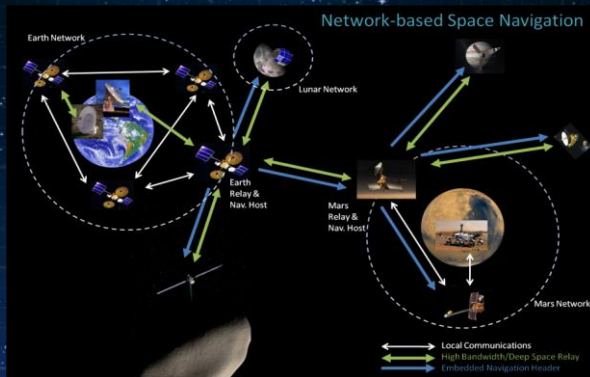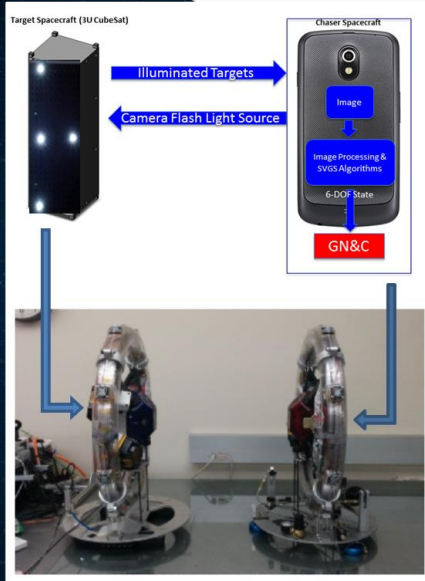 - Solar Sail Force and Moment Model
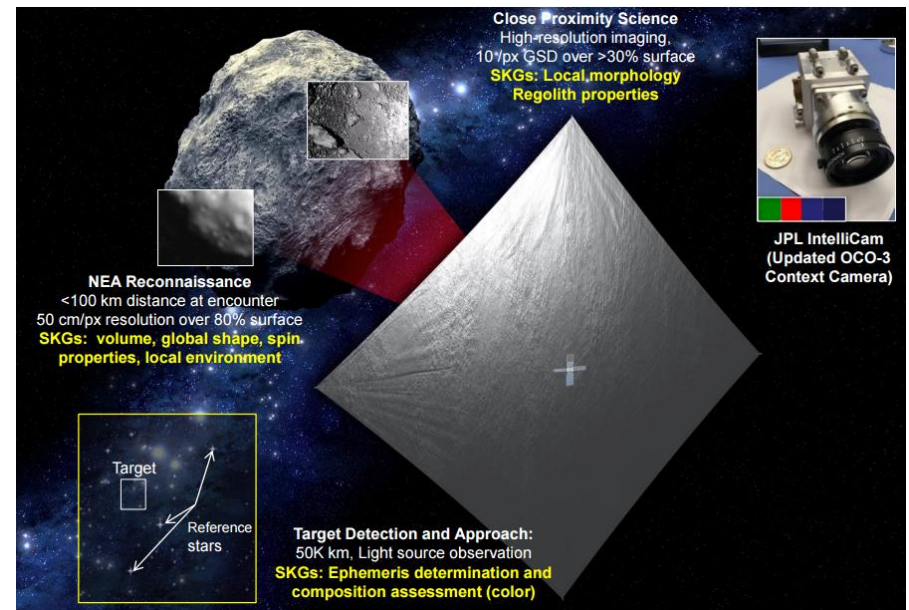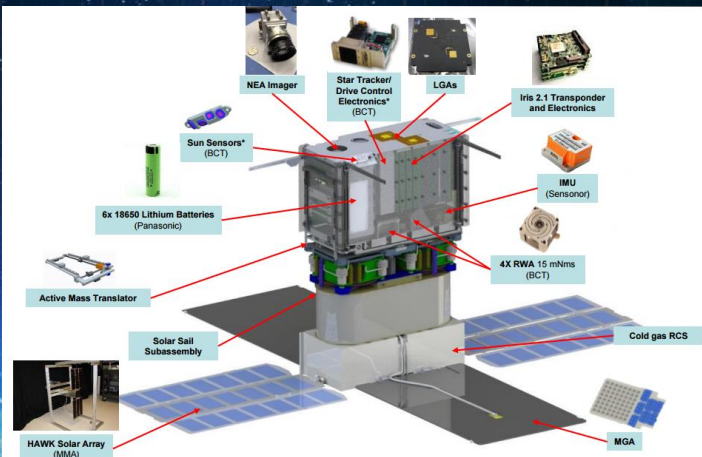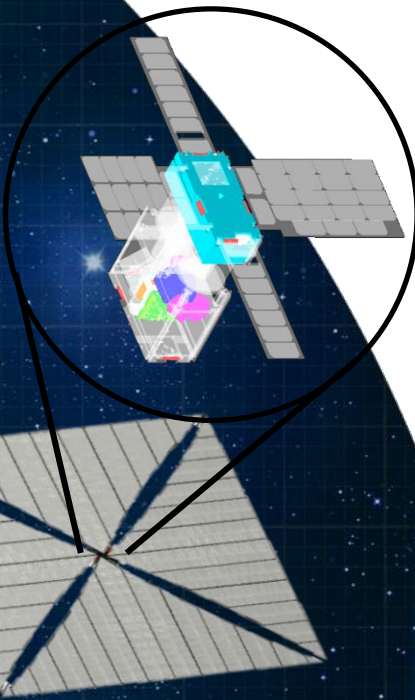
iSat

- Hall effect iodine thruster flight demo on 12U cubesat
- Full GN&C suite – reaction wheels, star tracker, sun sensor, Epson MEMS IMU, magnetometer, magnetic torquers, GPS
  - In-house GNC development effort
  - Using Simulink/Autocode to generate GNC flight software
  - Modeling flexible body motion of solar panels
  - Operational modes developed
  - Post-manuever thrust determination
  - Hardware procured, arriving at MSFC
  - Design capable of sub-100 arcsecond pointing
- Funded by STMD/Small Spacecraft Technology Program
- GNC and satellite bus at CDR-level
  - Propulsion system issues holding up CDR

GPS:
Spacequest
GPS-12

Magnetometer:
Honeywell
HMR2300

Sun Sensor:
Sinclair SS-411

Start Tracker:
Blue Canyon NST

IMU:
Epson M-G362

Reaction Wheels:
Blue Canyon
RWp100

Flight Software Commands

Sensor Processing

Navigation

Mag/Sun Model

Attitude Determination

Mode Control & Guidance

Control (Momentum Mgmt)

Torque Rods:
Blue Canyon
0.6 Amp-m²

Reaction Wheels:
Blue Canyon
RWp100

GNC Software

GNC Technology Development

- Smartphone Video Guidance Sensor (SVGS)
  - MSFC CAN with Florida Institute of Technology
    - RINGS integration and flat floor demo
    - Precursor to flying on SPHERES on ISS
- MAPS – "GPS anywhere" for deep space navigation – STMD GCD
  - Multi-spacecraft hardware-in-the-loop simulation
  - Building flight EDU for testing/calibration
  - Portable software library development
  - Proposing on-orbit demonstration on host platform(s)
- Nanolaunch
  - Providing testing support for AVA
  - Spherical air bearing-based testing
- AES Lander technology support
  - Agency GN&C lead for landers
  - Support commercial lunar lander efforts
  - Reaching out to incorporate TRN algorithms for vehicle assessment and design
- (Lunar) Resource Prospector
  - Leading GN&C oversight
  - Awaiting full buy-in from Taiwanese government
  - Possible EM-2 co-manifested payload
- Navigation-focused assessment of gyrocompassing and ascent performance from Martian surface