Multi Mission Operations Center

QuickTime™ and a
decompressor
are needed to see this picture.

NANOSATS

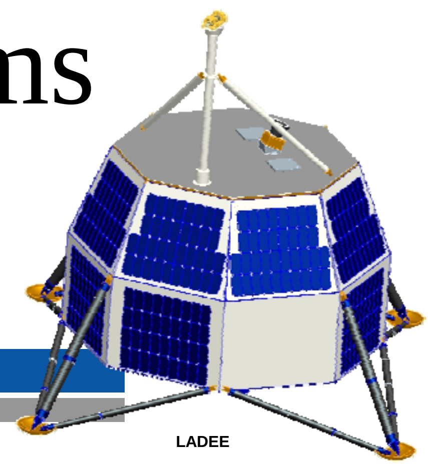
Looking
Towards the Future. . .

LCROSS

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

SMEX

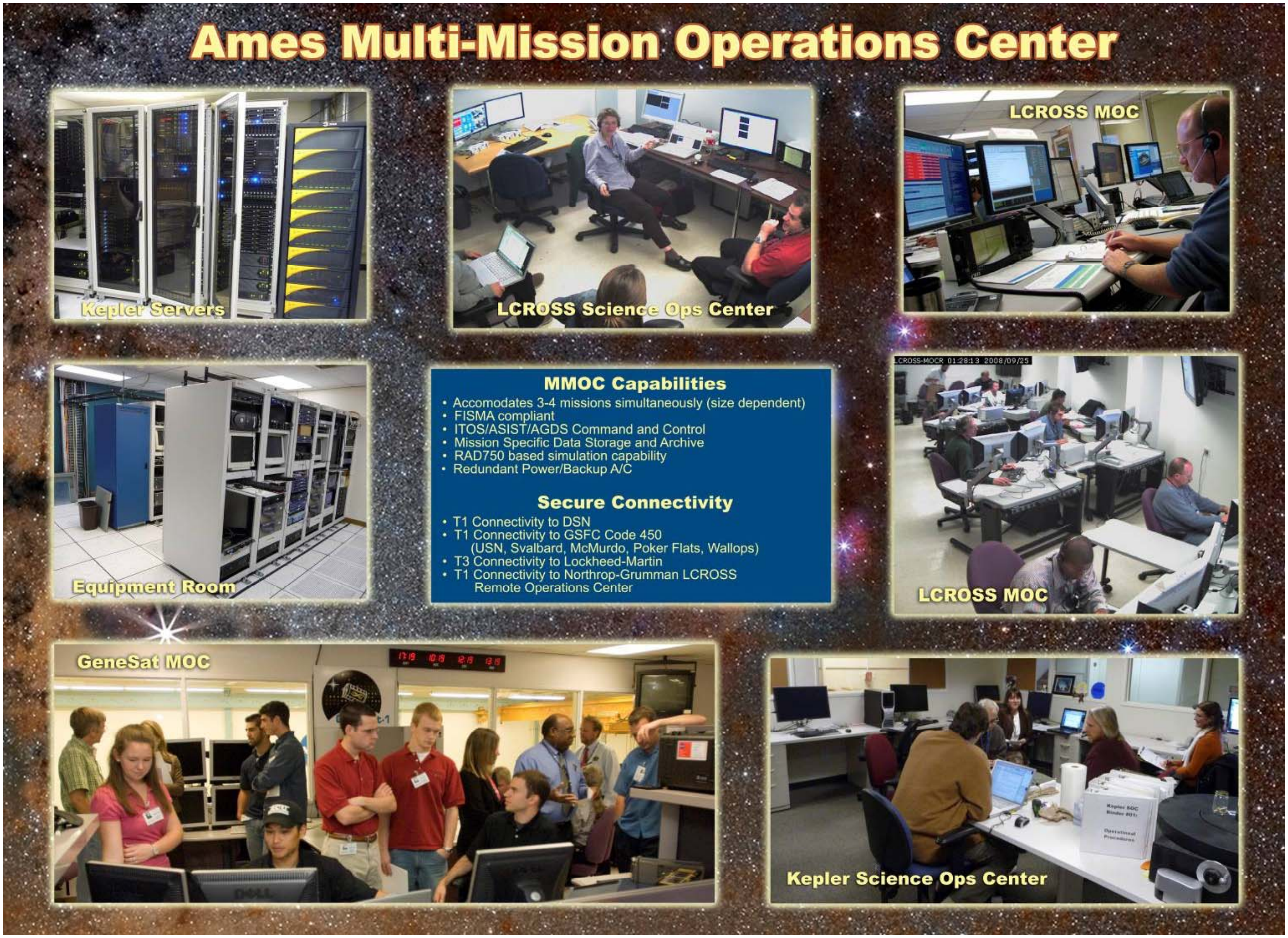
Introductions to Mission Operations & Ground Data Systems



LADEE

Ames Research Center

Mission Operations & Ground Data Systems



ARC Mission Operations

ARC MMOC capable of hosting multiple Mission Operations Software (MOS) options

- Biosat MOS : TCP/IP - UC Santa Clara Collaboration (GeneSat, PreSat, PharmSat)
- LCROSS: ASIST MOS
- LADEE: ITOS and components of Ames Ground Data Software (AGDS) MOS
  - *AGDS MOS: CCSDS - Java J2EE, Eclipse Framework, XML GUIs, Oracle database*
- Trade studies performed on MOS software (ASIST, AGDS, ITOS)

MMOC facilities at ARC contain: 3 MOCs, Mission Science Room, 2 SOCs, 3 conference facilities, including offices for MOS team

Recent missions: TROPI, GeneSat

Current Missions: LCROSS, ChipSat (monitor-only), PharmaSat, Kepler, LADEE ,SMEX(IRIS)

ARC MMOC Functions

- The ARC Multi-Mission Operations Center (MMOC) provides planning and implementation of Mission Communications Architecture for operations capability to command, control and monitor a variety of spacecraft and payload instruments
- Capabilities include:
  - Command and Control, including SPC/Command Sequence builds and execution
  - Command inhibits
  - Data distribution, processing, monitoring and archival (including video)
  - File Uploads to include SW loads/patches
  - Operations Planning
  - Engineering Analysis
  - Ground Data Systems development, operations and maintenance
  - SW Development and Maintenance
  - Science Ops support (e.g., SOC)
  - Flight Dynamics Support (visibility studies, link analysis, orbital determination etc.)
  - S/C simulation
  - Data communications with outside world, including video
  - Secured access and control (physical and electronic)

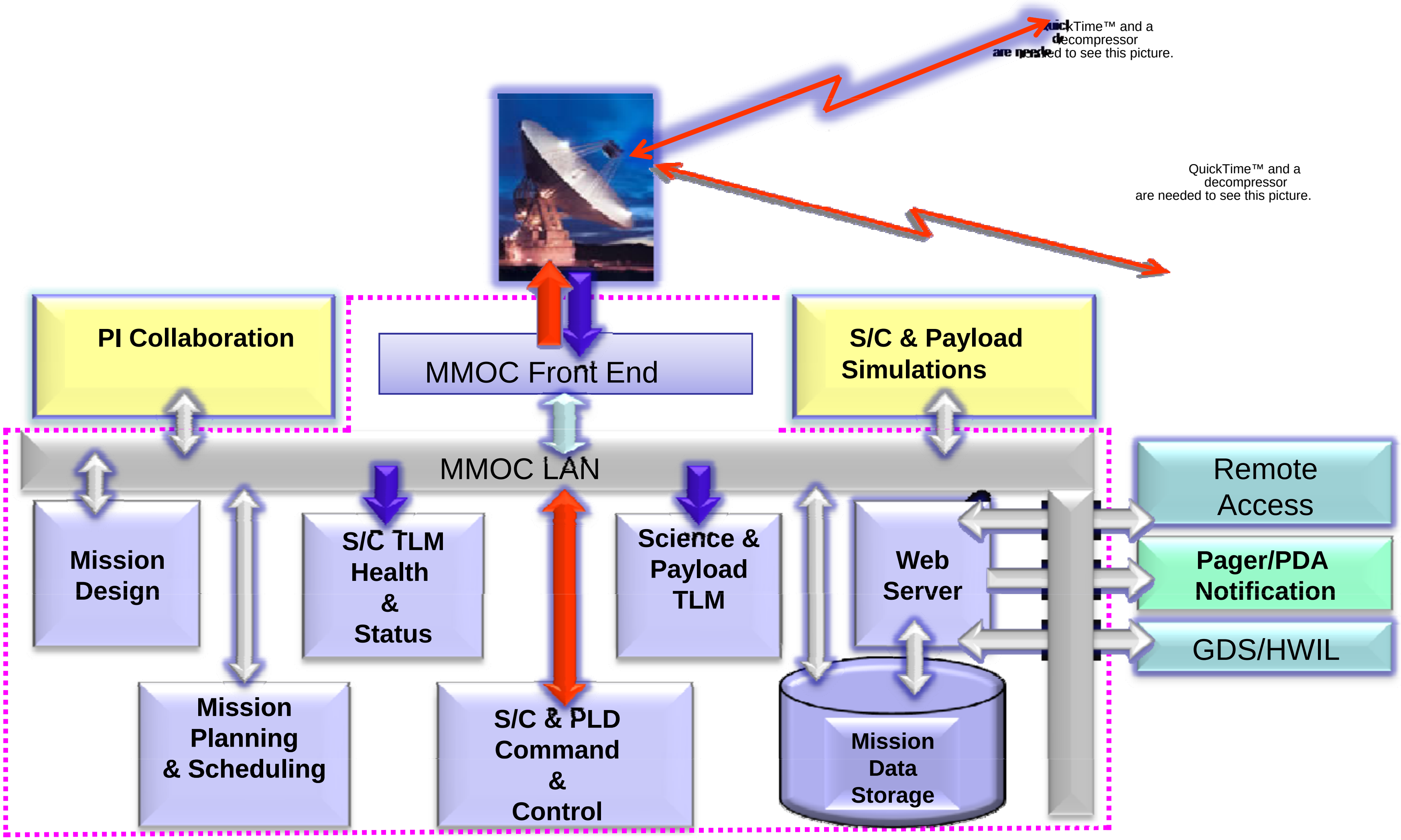
Communications Architecture

- In early concept studies the communications architecture plays an important part:
  - The communications architecture is the arrangement, or configuration of satellites and ground systems in given space system, and a network of communications links that transfers information between them.

Note that the geometry formed by the satellite's/spacecraft's orbit and/or planet's and/or landing site surface payload visibility, and ground station locations, which determines the basic Comm. Architecture. The PI determines the orbit from science and observation requirements.

- **Step 1:** Identify Communications requirements. To do this you need to develop a mission flow diagram based on mission requirements. In the diagram specify data sources, data end users, facility locations, quantity of data per unit time, access time, transmission delay, and even availability (reliability).
- **Step 2 :** Specify Alternative Communications Architectures, this is done by identifying links and ground station locations. Consider use of relay satellites and relay ground stations. Determine data processing location.
- **Step 3:** Determine data rates for each link. Determine sampling rates, quantization levels. Specify bits per sample
- **Step 4:** Design & Size each link, this is done by evaluating and comparing alternatives
- **Step 5.** Document reasons for Selection

MMOC Generic Configuration



Telemetry, Tracking and Command (TTC)

- Payload (on spacecraft and/or for surface operations) mission data and spacecraft housekeeping data pass from the spacecraft through this system to the operators and users at the operations center (s). Operators also send commands through this system to the spacecraft to control the craft and operate the payload.
- **Important for early concept design:** The Ground Data System and Mission Operations System lead designers must be involved with all mission design interface teams (especially spacecraft and payload design) and effectively communicate together on the design specs and requirements of the hardware, software and functions to pass the data reliably for all the spacecraft and payload operating modes.
  - Example: *The RF spectrum affects the satellite and ground station transmitter power, antenna size and beamwidth, and requirements for satellite stabilization. These factors affect satellite size, mass, and complexity*.
  - Subsystem functions:
    - ✓ Carrier tracking (lock on the ground station signal)
    - ✓ Command Reception and Detection (Uplink and processing of it)
    - ✓ Telemetry Modulation and transmission (accept data from spacecraft systems, process them, and transmit them)
    - ✓ Ranging (receiving, processing and transmitting ranging signals to determine the satellite position)
    - ✓ Subsystem Operations (processing of the subsystem data, maintain its own health and status, point the antennas, detect and recover faults.)
- The TT&C interfaces must reliably pass data back and forth or receive support from:
    - Attitude determination and Control
    - Command and Data Handling
    - Electrical Power Subsystem
    - Structure/Thermal
    - Payload
    - Propulsion

Designing the TT&C

- **Generally the development of a TT&C system starts with:**
  - Type of signal (voice, television, and data)
  - Capacity (number of channels and bandwidth)
  - Coverage area and ground site locations (local, regional, national, international)
  - Link signal strength (usually derived from spacecraft antenna and ground terminal type)
  - Connectivity (cross links, relay ground stations, and direct links)
  - Availability (link times (passes) per day and days per year, outage times)
  - Lifetime (mission duration)

- Constraints are limits on the TT&C subsystem from various sources. Many constraints arise during design, depending on the mission and the people involved.
  - **Power** constraints come from sizing the spacecraft and the power source (primary batteries, solar panels and secondary batteries, or radioisotope thermoelectric generator)
  - **Mass** constraints arise from the mass budget, which comes from the mission design and the chosen launch vehicle. The launch vehicle generally limits the total dimensions and mass, so individual subsystems receive their allocation within those limits. The launch vehicle also set the launch vibration and acoustic environment, which places constraints on the fragility of the subsystem.
  - When the **orbit** is chosen, it also sets the surrounding design, which in turn limits each subsystem. These cost constraints typically determine how much new technology and subsystem margin that the designers need to consider.
  - There are **international law and regulatory agencies** that impact design significantly. Because all spacecraft communicate with users and operators on the ground, de-conflicting frequencies, orbital locations, and power levels are critical to civilized sharing of limited resources. Designers must work with spectrum analysts who apply to the regulatory bodies for:
    - Communication frequencies (depending on the mission data rate, transmission power, and altitude)
    - Orbital assignment (2 deg from a satellite with the same frequency, if geosynchronous)
    - Desired power flux density on surface (dependent on receiver antennas)

Requirements

- Requirements for TT&C derives its requirements from many sources in early Pre Phase A and Phase A design:
    - Mission or science objective (top level requirements such as architecture, orbit lifetime, and environment)
    - The spacecraft/satellite (system level)
    - TT&C subsystem (internal requirements)
    - Mission spacecraft/satellite/payload subsystem requirements
    - Ground station and any relay satellite (e.g., TDRSS) compatibility
    - Mission Operations (MOS requirements)

- The above drive requirements in the TT&C subsystem:
    - Data rates (command and telemetry – spacecraft control, health, status mission and science needs)
    - Data volume
    - Data storage type
    - Uplink and downlink frequencies
    - Bandwidths
    - Received and transmit power
    - Hardware mass
    - Beam width
    - Effective Isotropic Radiated Power (EIRP)
    - Antenna gain/system noise temperature

Checklist for TT&C

- **Typical Basic Design Process (checklist) for TT&C:**
  1. Determine requirements
     – Range, orbit and spacecraft geometry
     – Data Rate and volume
     – Minimum elevation angle
     – Worst case rain conditions
     – Bit error rate
  2. Select Frequency
     – Typically an existing, assigned frequency
  3. Determine required bandwidth
     – Use Shannon's theorem, primary driver is data
  4. Do Major subsystem trades between (Use link budget to trade between components):
     – Receiver noise temperature
     – Receiver gain (antenna aperture)
     – Transmitter gain (antenna aperture)
     – Transmitter power
  5. Do major subsystem trades between the TT&C subsystem and other subsystems
     – Understand the satellite's sensitivity to each TT&C subsystem design feature
  6. Calculate performance parameters
  7. Estimate subsystems weight and power
  8. **Document reasons for selection (Very important to document assumptions)**