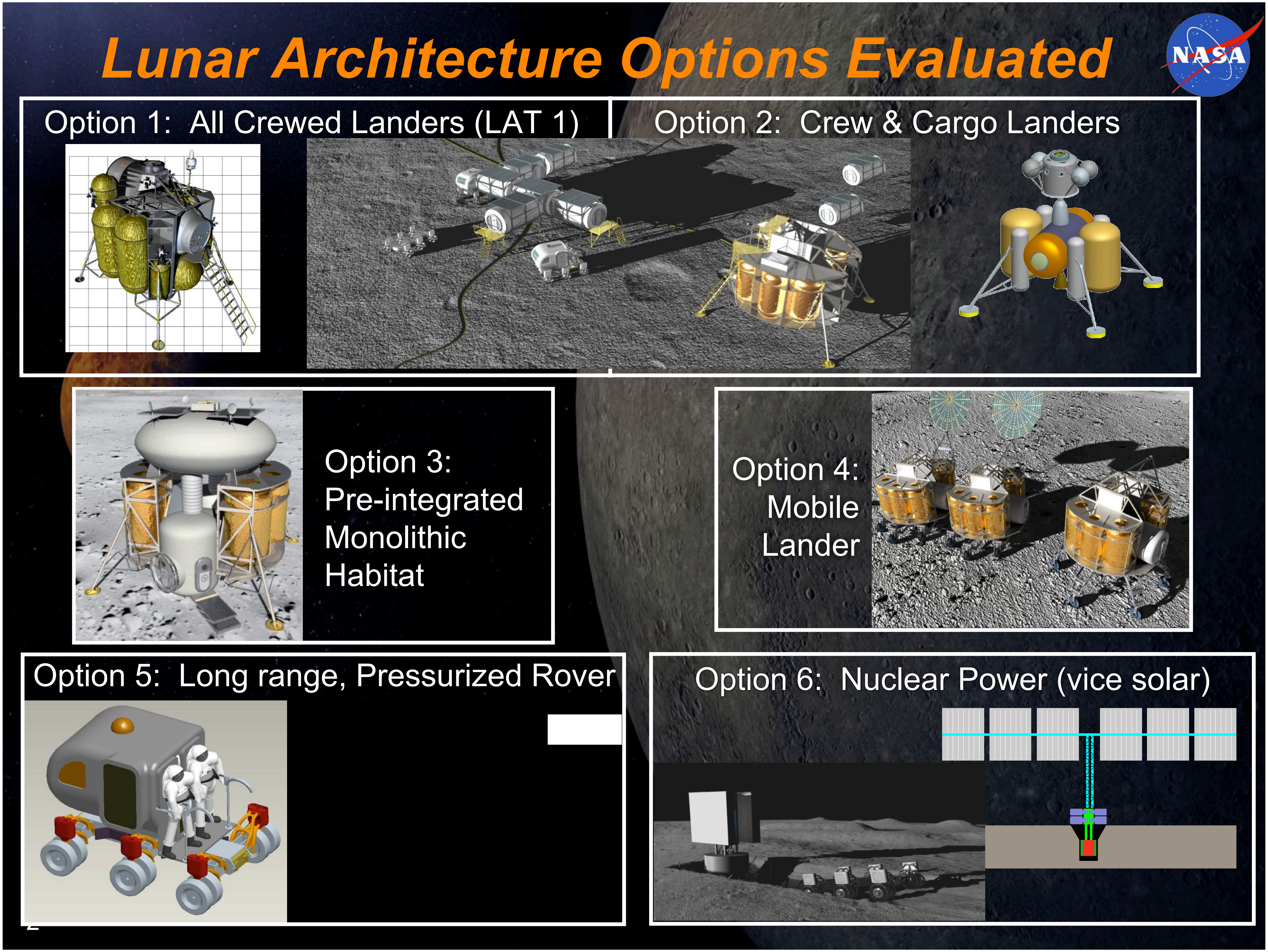
National Aeronautics and Space Administration

NASA's Lunar Communications & Navigation Architecture

Technology Exchange Conference

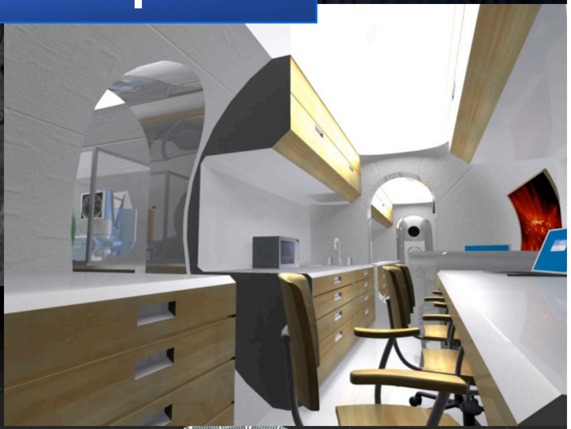
15 November 2007


Lunar Architecture Options Evaluated
NASA
Option 1: All Crewed Landers (LAT 1)
Option 2: Crew & Cargo Landers
Option 3: Pre-integrated Monolithic Habitat
Option 4: Mobile Lander
Option 5: Long range, Pressurized Rover
Option 6: Nuclear Power (vice solar)

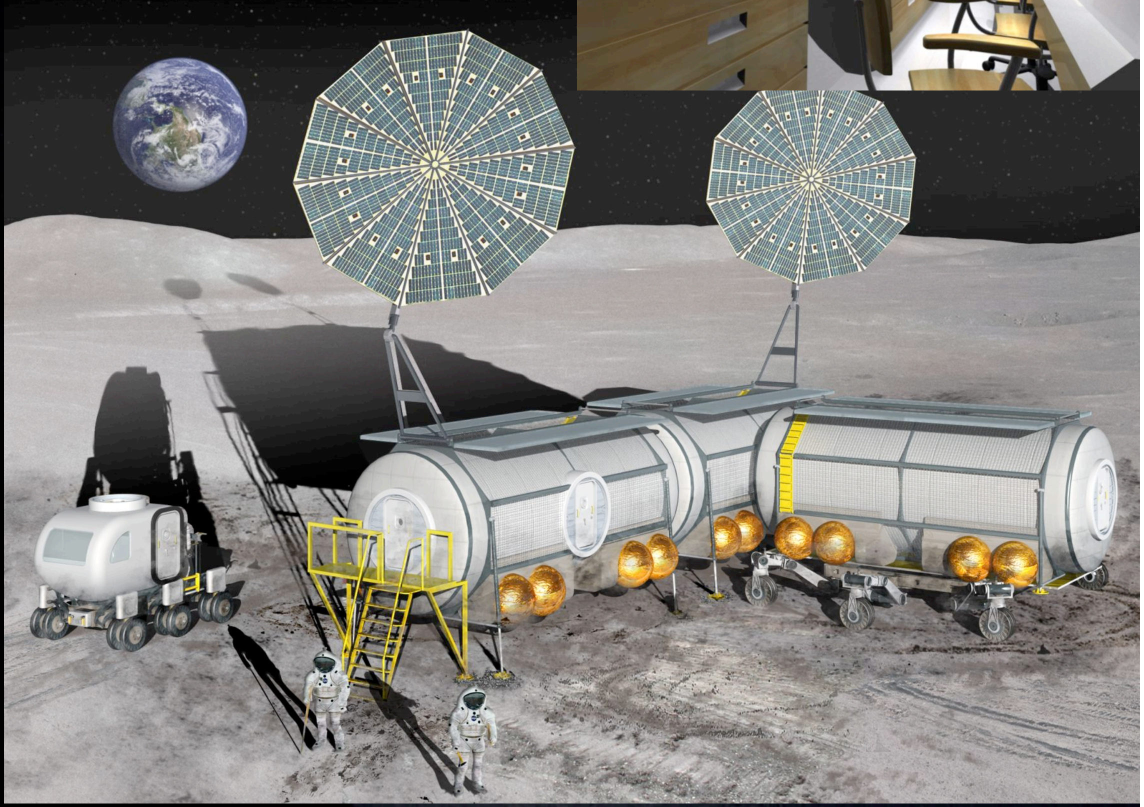
Hybrid Approach to Architecture

A flexible architecture incorporating best features and lessons learned from all the Lunar Architecture Team options

Surface Architecture - Discrete elements sized smaller than the monolithic unit, but larger than the mini-hab concept



- Cargo lander needed for robustness
- Outpost built up from 2-3 hab elements
- Assembly facilitated from separate surface mobility system
- Make maximum use of delivered hardware to minimize the bone yard
- Early delivery of small, agile pressurized rover that carries SPE protection; suit lock



C&N Focus Element Summary

Overview

C&N services are provided via Relays & surface Lunar Comm Terminals (LCT) for the outpost with periodic Direct To Earth (DTE) capability. Relays cover entire lunar surface for sorties.

Concept of Operations

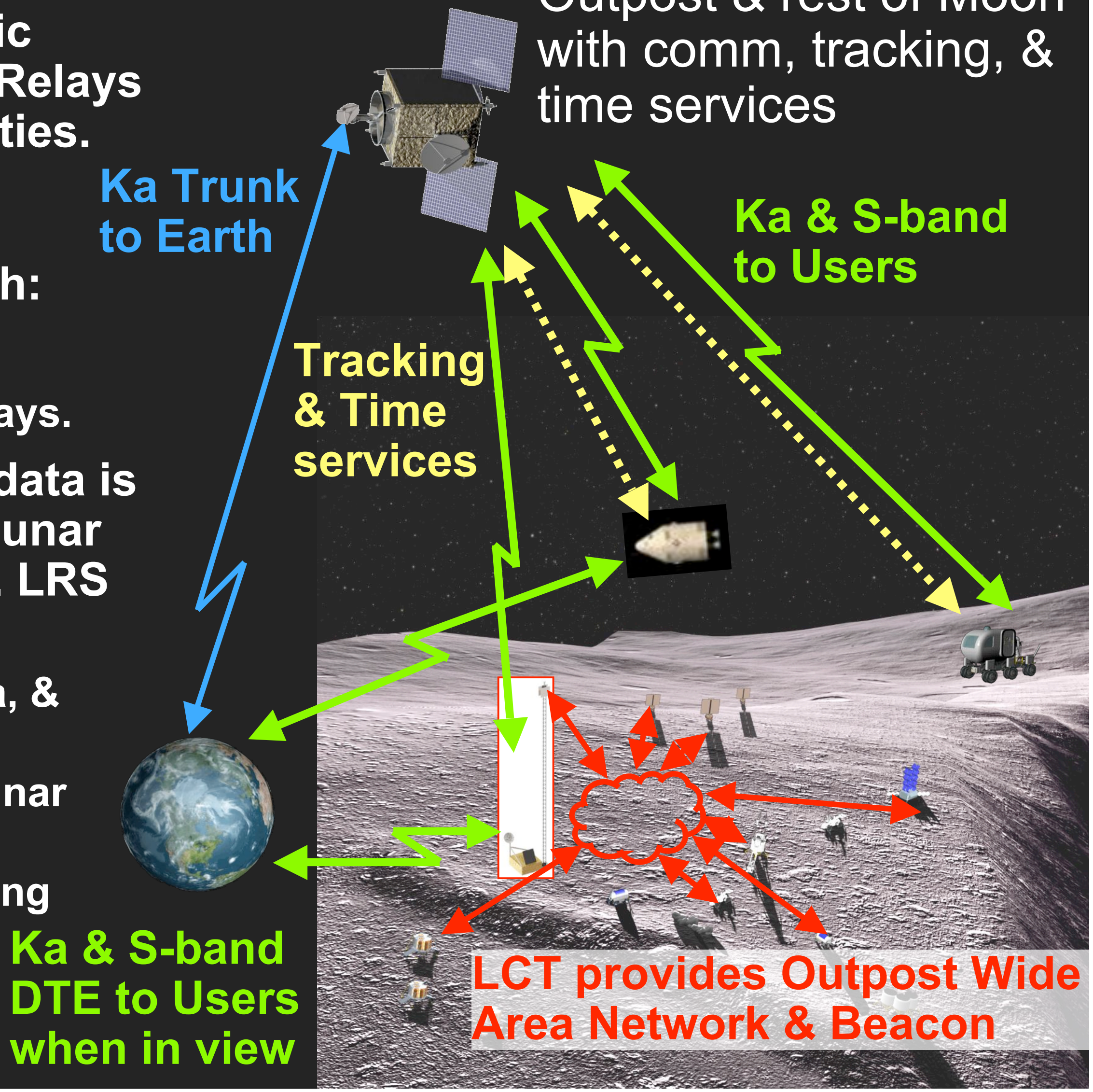
There is redundant comm to Earth:

- **Early missions via DTE and 1 relay**
- **Extended missions via DTE & 2 relays.**

For surface operations, Outpost data is routed through the LCT to other lunar users or to Earth via DTE or LRS. LRS & LCT provide these services:

- **Forward & return voice, video, data, & TT&C**
- **Fully routed data between Earth, lunar orbit, & lunar surface users**
- **1 & 2-way ranging & Doppler tracking**
- **Surface Navigation Beacons**
- **Time dissemination & synchronization**

Lunar Relay Satellite (LRS): Coverage of Outpost & rest of Moon with comm, tracking, & time services



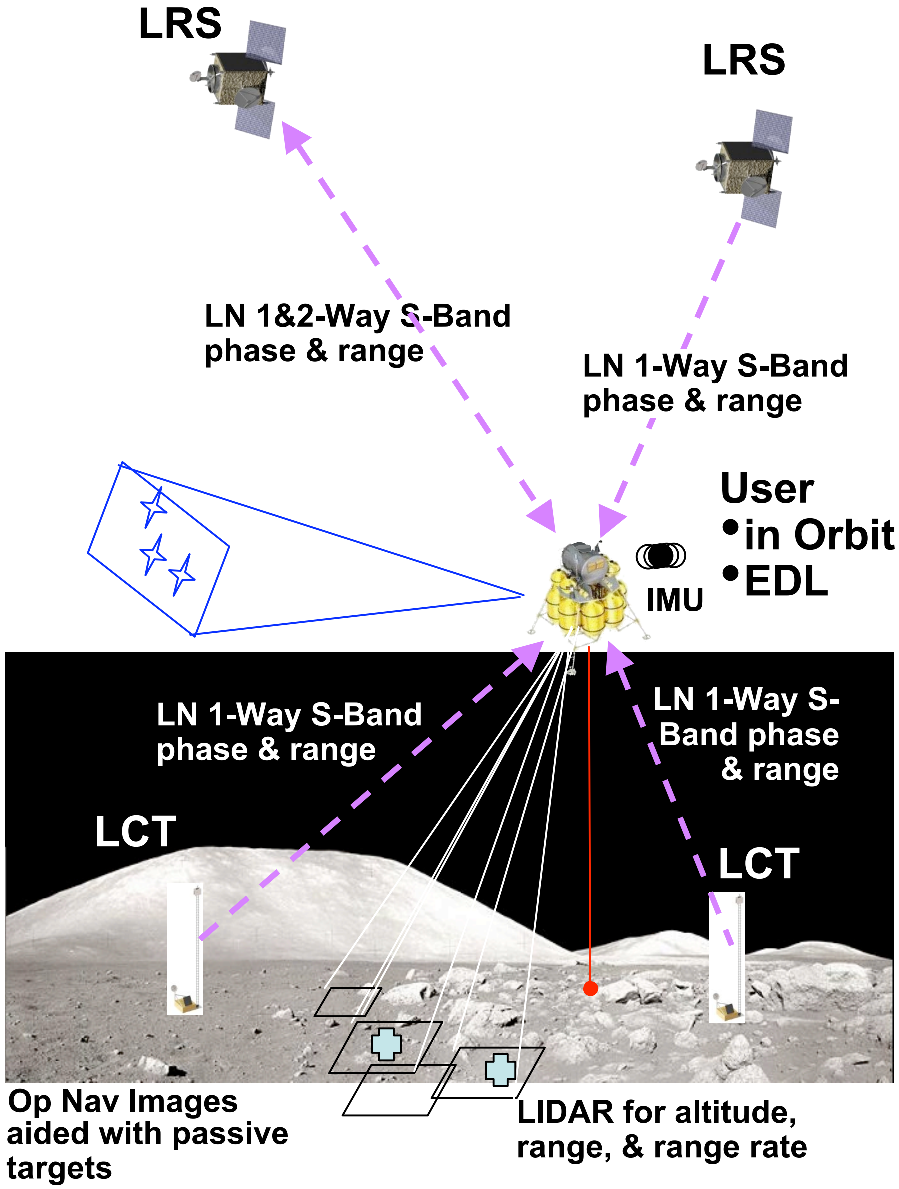
Traffic Model Summary

Description	Applicable System(s)	Data Rates (without explicit margin added)		
		Low Rate (Mbps)	**High Rate** (Mbps)	**Total Rate** (Mbps)
Aggregate Peak Rate to Earth	LRS and Earth Ground System	3.9	151.0	**154.9**
Aggregate Peak Rate from Earth	LRS and Earth Ground System	1.1	66.0	**67.1**
Aggregate Peak Rate Up to LRS from Lunar Surface	LRS and LCT	6.4	216.0	**222.4**
Aggregate Peak Rate Down from LRS to Lunar Surface	LRS and LCT	6.1	141.0	**147.1**
Aggregate Peak Rate Across Lunar Surface	LCT	8.7	143.0	**151.7**

- **The aggregate peak rate to and from Earth will occur between the LRS and the Earth Ground System in the 37/40 GHz band.**
- **The aggregate peak rate up to LRS and down from LRS relative to the lunar surface will have to be apportioned between the S-band and 26/23 GHz band links occurring between:**
  - **LRS and LCT (when all surface elements are in sight of LCT)**
  - **LRS and LCT + mini-LCT + Mobile User Radios + EVA Suit Contingency Comm**
- **The aggregate peak rate across the lunar surface pertains to the 802.16 capacity of the LCT when all surface elements are in sight.**

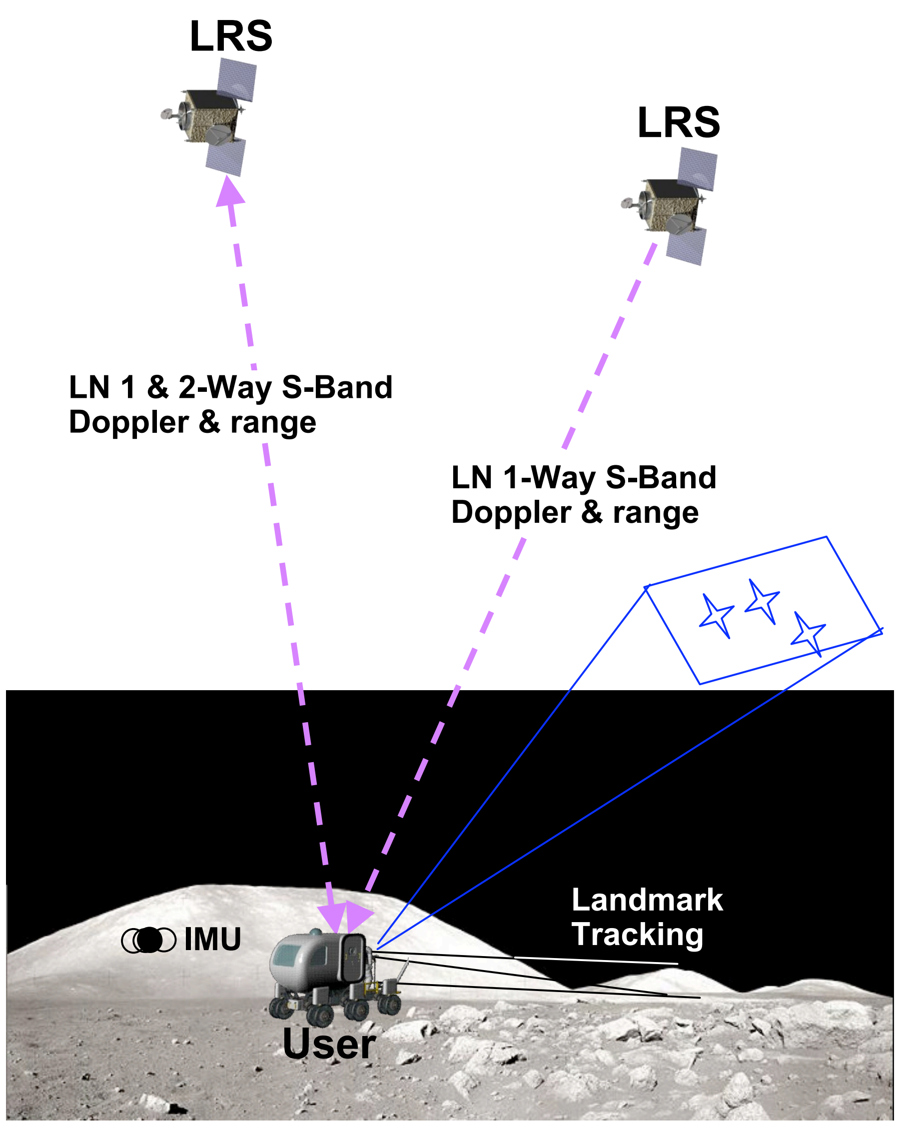
Descent & Landing Navigation

- **Autonomous Landing Mode:**
  - ALHAT-based landing without active optics provides a self-contained system with IMUs
  - Designing to 100 m (3-σ) level landing accuracy assuming no emplaced infrastructure (i.e., relays)
  - Passive optical system + strobe lights for use in the last 300 m for low light landing situations
  - IMU data required for thrust level sensing
  - All data (RF, Optical, LIDAR/RADAR and IMU) processed in real-time for continuous trajectory update to closed-loop guidance system
- **Infrastructure-aided Landing Mode:**
  - LN-aided descent/landing augments a passive optical-based landing system by providing accurate radiometrics to maintain trajectory knowledge through powered descent and landing in view of emplaced landing aids
  - Anticipate 1 meter level landing accuracy
  - Landing aids near outpost are a combination of passive optical devices and LCTs that operate like the LRS
  - Radiometrics disciplined by an atomic clock

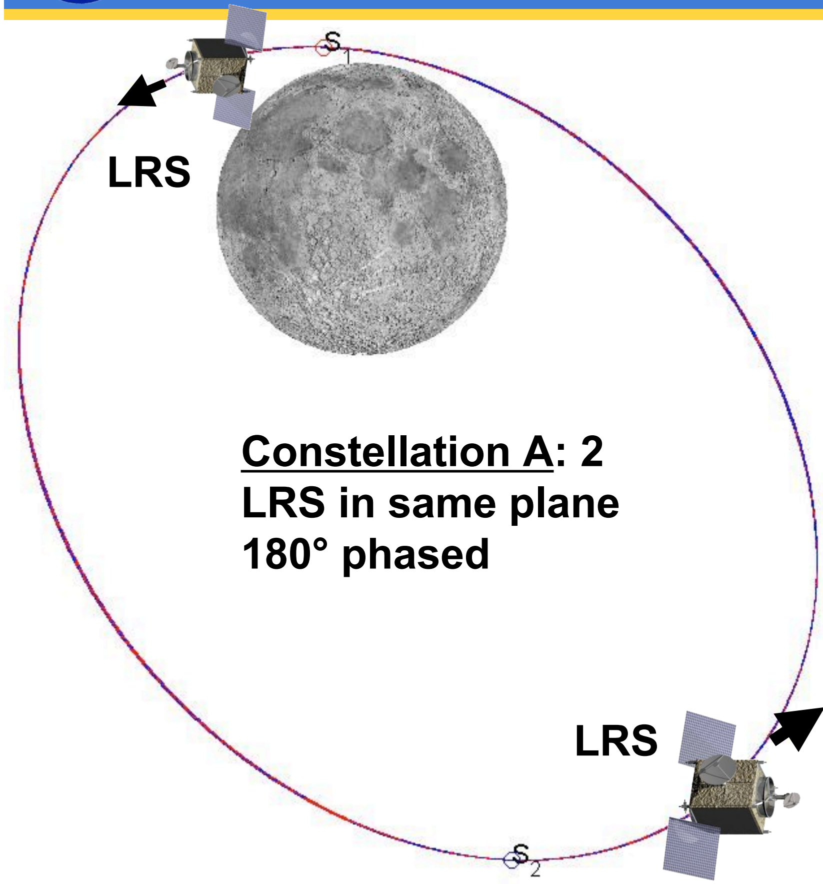


Surface Mobility Excursion Navigation

- Surface mobility may involve excursions that are 500+ km from the outpost
  - Farside trek has no DTE or LCT
  - Position knowledge $\leq$ 30 m needed to navigate to desirable spots and back home
  - IMU insufficient for in-situ navigation (1200 m long term accuracy)
- LN tracking and imaging required
  - Roving navigation requires periodic stops to obtain in-situ static position fixes ~every 30-60 min
- In-situ static positioning fixes require
  - LN radiometric tracking to obtain inertial position
  - Landmark tracking coupled with star tracking to obtain map relative position
  - Combined process resolves the 'map tie' error between inertial and map relative solutions
  - Static position to < 10 m in a few minutes
- Roving navigation is initialized via the static position fix and then continues with real time navigation processing
  - IMU data is dead reckoning velocity
  - LN radiometric tracking to solve for position and velocity and 'disciplining' IMU drift
  - Image data not taken while roving

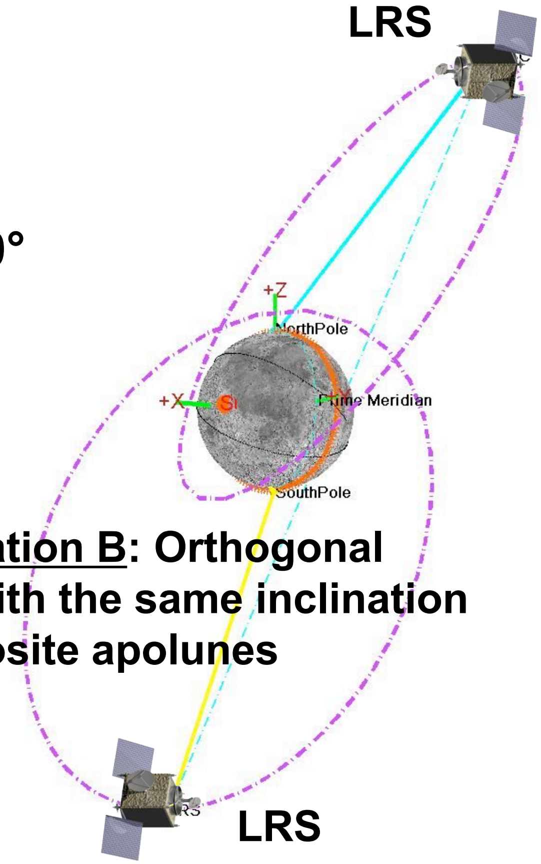


Sortie Support



Constellation A: 2 LRS in same plane 180° phased

LRS:
- **SMA= 6142.4 km**
- **Eccentricity=0.59999**
- **Inclination=57.7°**
- **Perilune Argument=90°**
- **12-Hour Orbits**

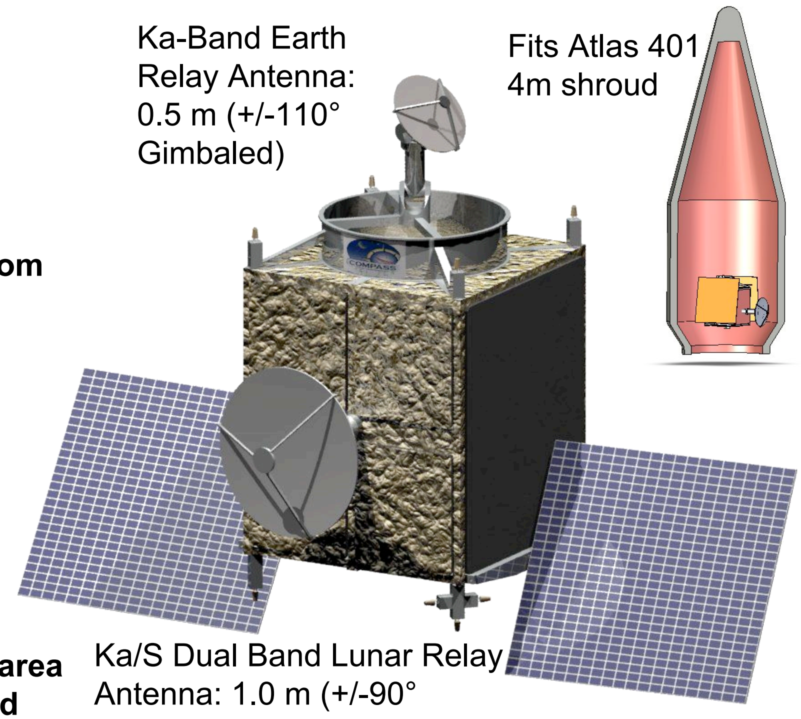


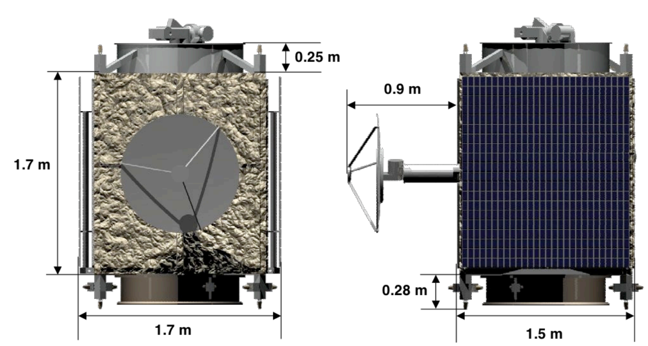
Constellation B: Orthogonal planes with the same inclination and opposite apolunes

- **Using LRS as designed (i.e., no additional NRE or RE), operational options are available to support missions over the entire lunar surface at the same level of performance**
  - **Tradeoff: Two relays in the same orbit provides good coverage of 1 hemisphere with an operational satellite plus on-orbit spare. Two relays in different orbits provides full surface coverage at the expense of no on-orbit spare.**

Lunar Relay Satellite (LRS)

- **Lunar comm relay, navigation & timing spacecraft**
  - 2 LRS in 12 hr frozen elliptical lunar orbit
  - 7 year life with fuel for 10 years, Each LRS single fault tolerant
- **Atlas 401 or Delta IV Medium: >60% launch margin**
  - Options exists for dual launch or secondary payloads
- **Communications and Navigation Payloads**
  - 2x100 Mbps high rate links from Surface, 2x25 Mbps low rate from other surface; Fully IP-routed
  - 2-way ranging to up to 5 users simultaneously
  - 24 hr Store & Forward with 300 GB
- **Prop:** Pressure Fed Hydrazine, 2x100 lb_f & 16x 0.5 lb_f thrusters
- **C&DH:** command, control, health management
- **Attitude Control & Navigation**
  - 20 Nms momentum storage in 4 reactions wheels
  - 12 sun sensors, 2 star trackers, 2 IMUs
- **Power: 1040 W Average Power Load (30% margin)**
  - 2 1-Axis Solar Arrays, 28% efficient triple-junction cells, 4.7 m^2 area
  - 137 Ah BOL Li-ion batteries, 2.5 hr eclipse at full power, reduced ops for 5 hr eclipses
- **Thermal:** Heat Pipe-Radiator System, Hydrazine Heaters
- **Mechanical:** Al-Li Panel around a central thrust-tube

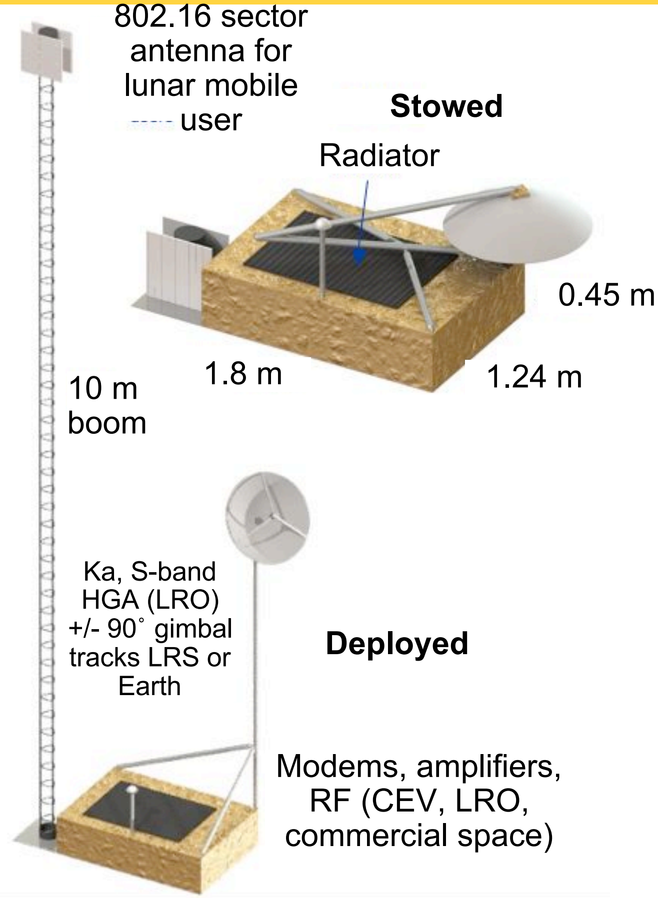


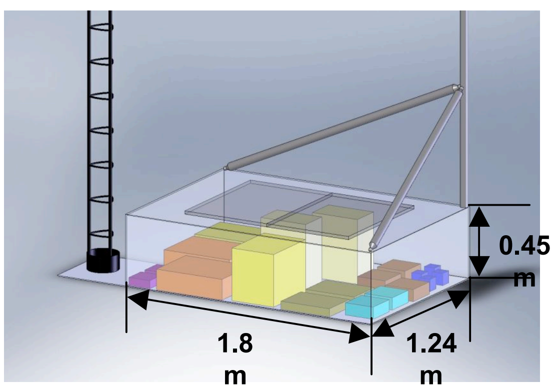


Description 1.8.3.1 & 1.8.3.2 Lunar Relay Satellite 1st Unit & 2nd	CBE Mass (kg)	Growth (kg)	Total Mass (kg)	Nominal Power (w)
Lunar Relay Satellite	1033.5	90.8	1124.2	683.6
Communications	79.4	2.4	81.8	494
Avionics	91.6	21.7	113.3	189.6
Structures & Mechanisms	180.5	25.1	205.6	0
Power System	72.6	22.2	94.8	0
Propulsion (Chemical)	21.8	1.7	23.5	0
* Propellant Management	72.9	10.9	83.9	0
* Propellant	467.3	0	467.3	0
Thermal Control	47.3	6.7	54	0

Lunar Communication Terminal

- **Communications**
  - 80 Mbps 802.16e WLAN for lunar surface, 5.8 km range
  - 200 Mbps Ka to LRS (or Earth)
  - 25 Mbps S-band to LRS (or Earth); 192 kbps safe mode
- **Command & Data Handling**
  - 0.3 TB data recorder, general avionics processor
  - Time generation unit, atomic clock
- **Power from lunar grid**
  - 200 m power cable/reel
  - DC-DC converter: 270V outpost-28V LCT
- **Structure & mechanisms**
  - Al box, tubular frame with panels
  - Deployable 10 meter boom; Ka antenna mast
- **Thermal Control (-20C to 50 C)**
  - Radiator, heat pipes, cold plates, MLI, heaters, thermocouples, heater/MLI on boom



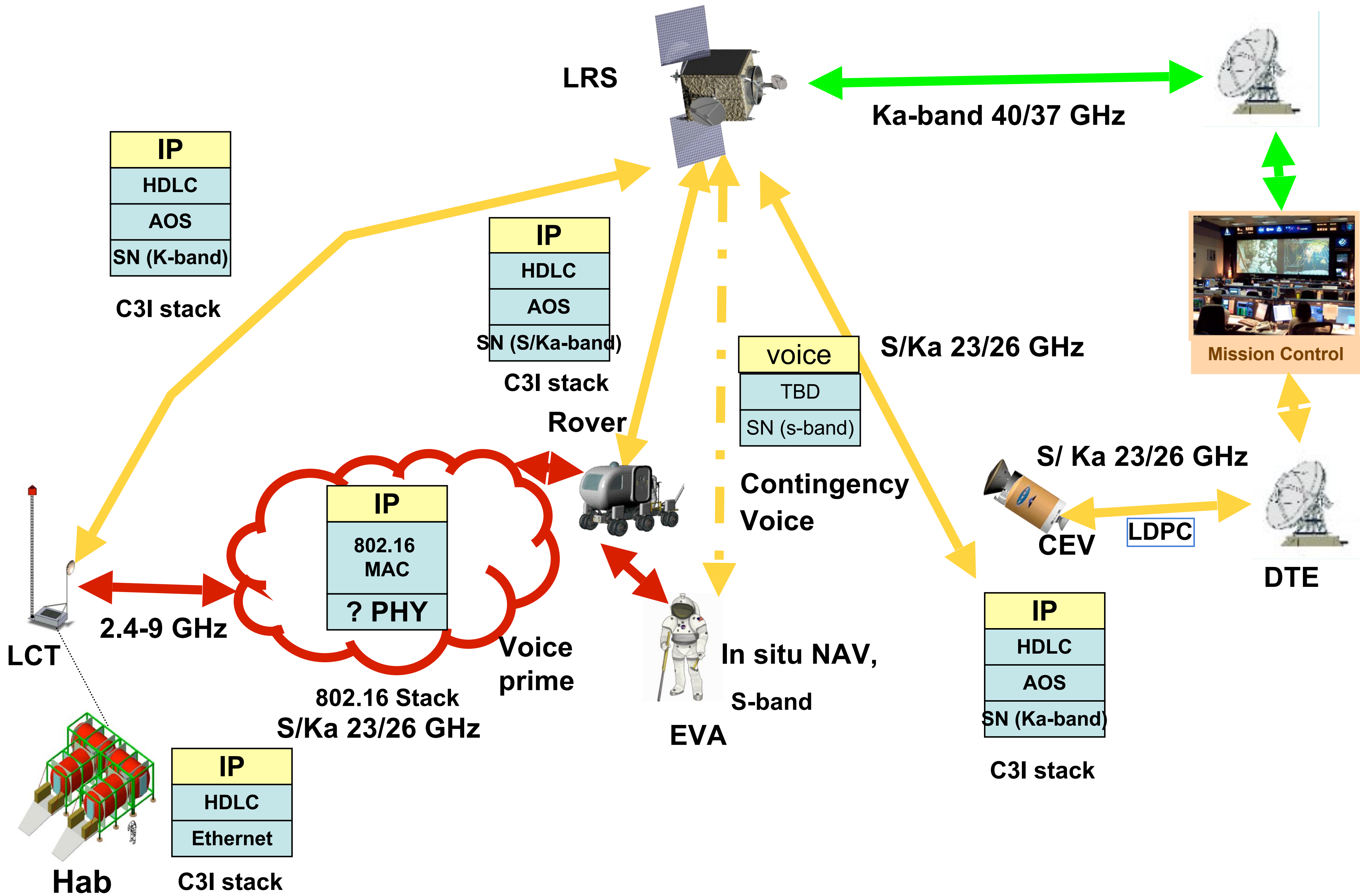


Description Deployed LCT	**CBE Mass (kg)**	**Growth (kg)**	**Total Mass (kg)**	**Nominal Power (w)**	**Peak Power (w)**
Lunar Comm Terminal	349.4	68	417.4	420.8	450.8
Communications	85.6	18.6	104.2	258.2	288.2
Command & Data Handling	62.5	15.6	78.1	162.6	162.6
Power System	46.8	20.1	66.9	0	0
Structures & Mechanisms	88.6	9.1	97.7	0	0
Thermal Control	66	4.6	70.5	0	0

User Radios – Product Line

Capability	Fixed Base User Radio	Mobile User Radio	EVA Suit Radio
802.16 Wireless LAN on lunar surface	Base station, 11.2 Mbps to LCT to create remote WLAN or back up LCT	Cell phone & 11.2 Mbps video in Normal Mode; 2 Mbps from EVA Suit in Self Sufficient Mode	Cell phone: 2 Mbps to LCT, Rover, or portable Fixed Base Radio in Normal Mode.
Ka/S band dual feed antenna for high rate data to LRS or Earth	20 Mbps Ka and 192 kbps S band in Self-Sufficient Mode or to back up LCT	Folded up to protect from dust in Normal Mode; 9.5 Mbps Ka & 192 kbps S band in Self Sufficient Mode	N/A. Astronaut relies on LCT, Rover, or portable Fixed Base Radio.
S band TDRSS antenna	192 kbps navigation in Normal Mode or Safe Mode	192 kbps nav in Normal Mode 19 kbps nav/voice in Safe Mode	Contingency Mode: 8 kbps voice & 2-way nav
Navigation	2-way nav (position & ranging) via TDRSS S band in SN protocol	2-way nav (position and ranging) via TDRSS S band in SN protocol	Relies on Rover in Normal Mode. 2-way nav in Contingency Mode
Mass – current best estimate (CBE) + margin	269.7 kg CBE 319.8 kg w/ growth allowance	26.4 kg CBE 30.5 kg w/growth allowance	1.2 kg CBE 1.4 kg w/growth allowance
Power required from Host Element	131.6 watts	28 watts Normal Mode; 54 watts Self Sufficient Mode	4 W Normal Mode; 12-15 W Contingency Mode

Surface Architecture – Network Protocols

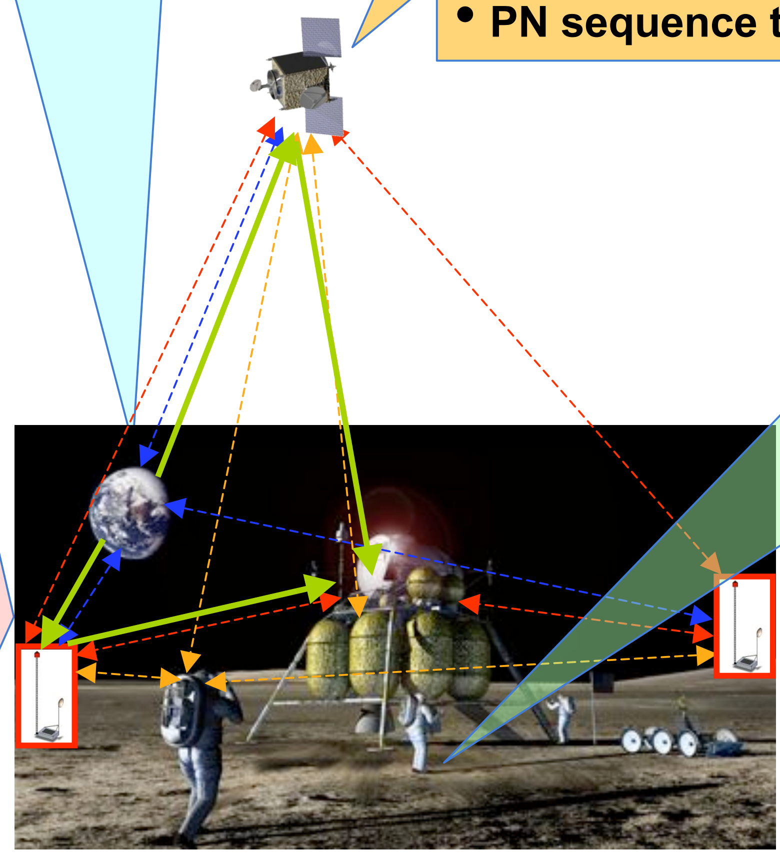


LN Radiometric Time Architecture

Earth
- Maintains common time base
- Initiates 2w radiometrics w/LRS & Lunar surface elements
- Produces Navigation Message

LRS Transceiver
- Atomic Time & Frequency standard
- Disseminates Navigation Message on Tx forward link
- Radiometrics can be initiated & measured for 2w, telemetered to user
- Radiometrics can be initiated @ LRS and measured by user for 1w
- PN sequence tied to epoch

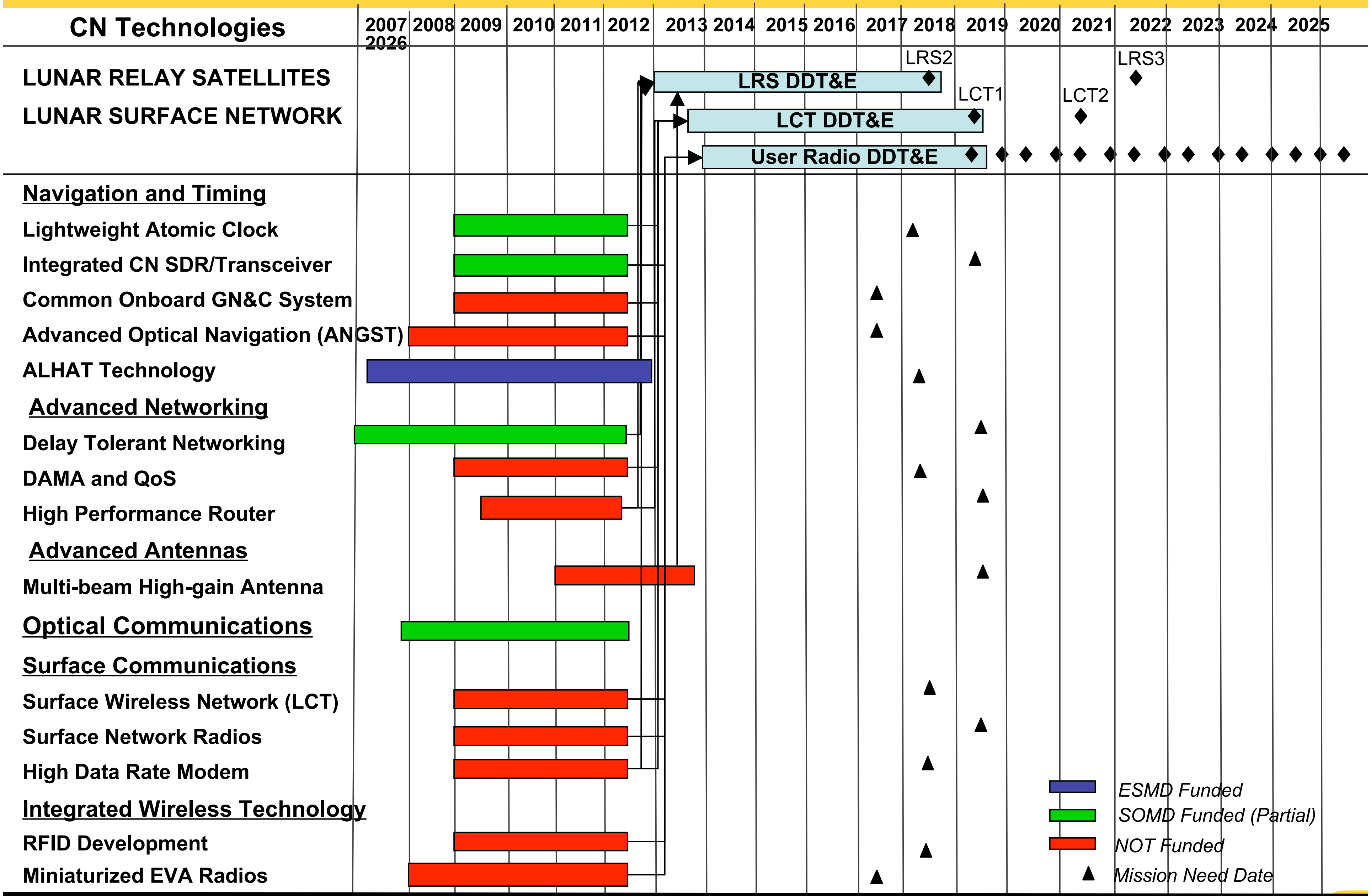
LCT Transceiver
- Atomic Time & Frequency standard
- Disseminates Navigation Message on Tx forward link
- Radiometrics can be initiated & measured for 2w, telemetered to user
- Radiometrics can be initiated @ LRS and measured by user for 1w
- PN sequence tied to epoch



User (Lander, Rover, EVA)
- USO to wrist watch
- Transponder* (multiple Rx: 2w to one element, 1wF from all others)
- Demodulate Navigation Message
- Radiometrics can be measured from LRS & LCT forward signals

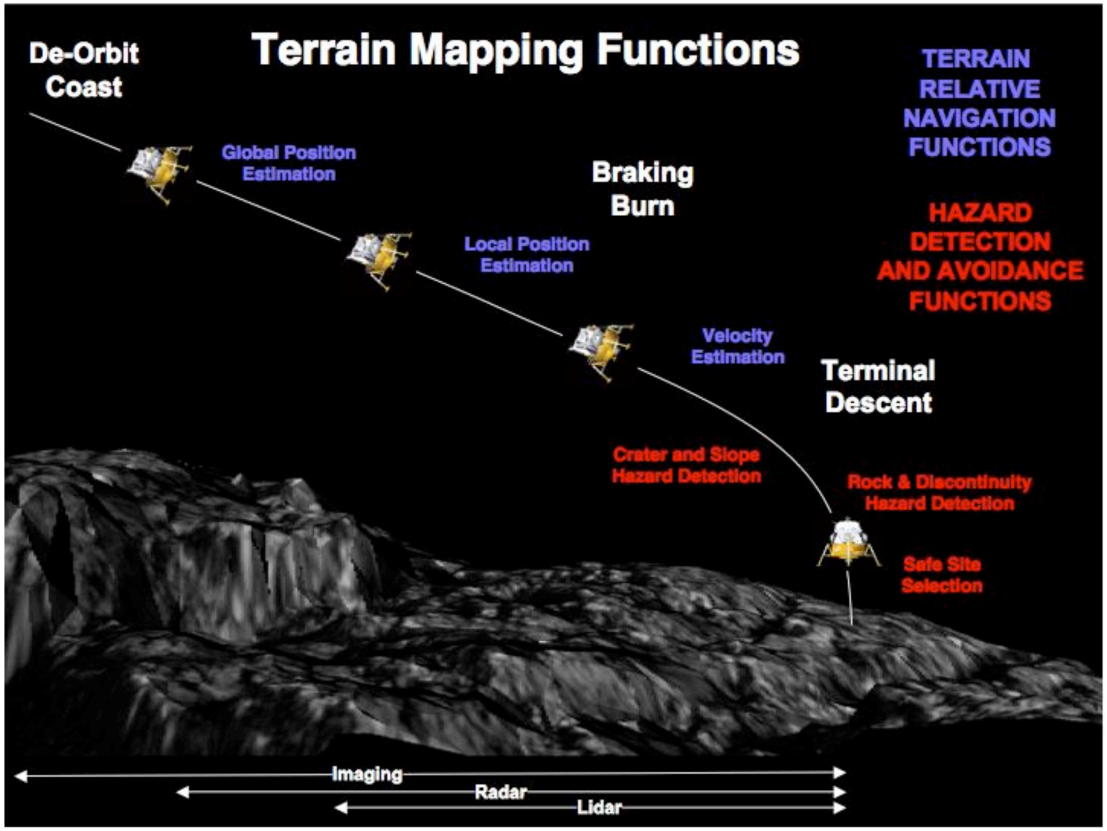
* Transceiver if only 1w needed

C&N Technology Roadmap



Autonomous Descent & Landing – ALHAT

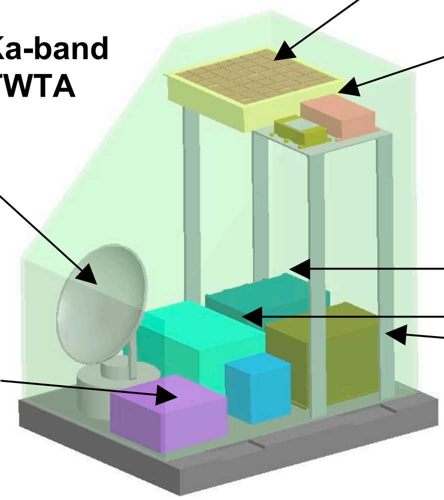
- **Autonomous Landing and Hazard Avoidance Technology (ALHAT) landing developing technology for a self-contained landing system**
  - Terrain Relative Navigation (TRN) used for high-altitude, target relative guidance – flash LIDAR/passive optics is current trade
  - Hazard Detection & Avoidance/Navigation (HDA/HRN) at lower altitudes with scanning LIDAR used for retargeting to safe locale
  - Other sensors include precision IMU and RADAR altimeter
- **100 m (3-σ) landing accuracy in any lighting condition at any time**
  - Assumes no emplaced infrastructure (i.e., relays, surface aids)
  - Any lighting condition → active optics such (LIDAR) in HDA/HRN phase
- **All TRN/HDA data, RADAR and IMU processed in real-time for continuous trajectory update to autonomous closed-loop guidance system**
  - Accommodation for crew-redirects in later part of the HDA phase



Communications, Navigation, and Networking reConfigurable Test-bed (CoNNeCT)

Description and Objectives

- Demonstrate on-orbit SDR/STRS performance and operations from multiple suppliers
  - Raise SDR technology and STRS Architecture to TRL-7 for mission adoption.
  - Reduce dependence on particular vendors for SDR software updates, reducing future cost risk
- Use reconfigurable systems to validate different communications capabilities (e.g. STRS updates, modulation, coding, security, networking) at TRL-7
- Assess GPS for orbit position accuracy and integrity
- Assess the communications, pointing and tracking performance and operation of TDRSS at Ka-band.



Approach/Benefit

- Extend SDR/STRS laboratory testbed to space to achieve higher TRL and better integrate SDR technology and operations.
- Conduct suite of individual experiments from different Centers and industry partners to assess SDR/STRS on-orbit performance.
- Leverage multi-Center expertise to develop the CoNNeCT payload.
- Expand cooperative partnerships to include mid-level TRL flight hardware assessments.

PI/Partners

PI: Richard Reinhart, GRC

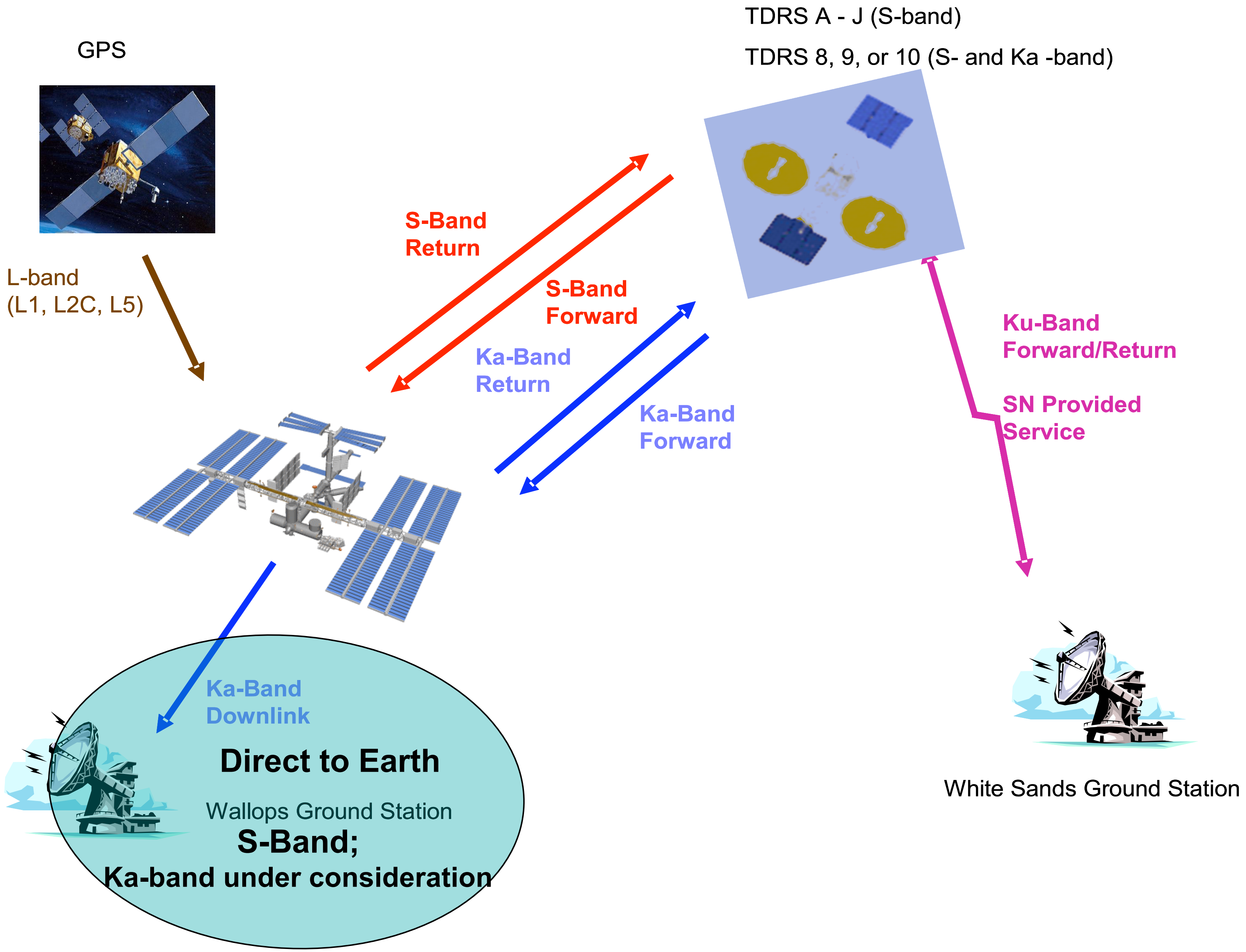
Co-I: Dave Israel, Biren Shah, Oron Schmidt

Industry Participants: TBD

Activities

- 4Q07- Cooperative solicitations & awards for payload hardware
- 1Q08- Experiment Plan, conops, costs, design
- 1Q08- Antenna placement & coverage trades
- 3Q08- Preliminary Design Review
- 1Q09- Critical Design Review

CONNECT System Diagram



Navigation and Timing Technology

Integrated Transponder/ Receiver for Navigation Using SW Defined Radio (SDR) Technology

A radio with integrated communications and tracking functionality would requires less spectrum, mass, power, and volume allocations; all of which may be in limited supply. A software radio that integrates radiometric tracking, communications, and autonomous navigation would provide a robust, flexible, and economic platform for supporting localized and surface navigation.

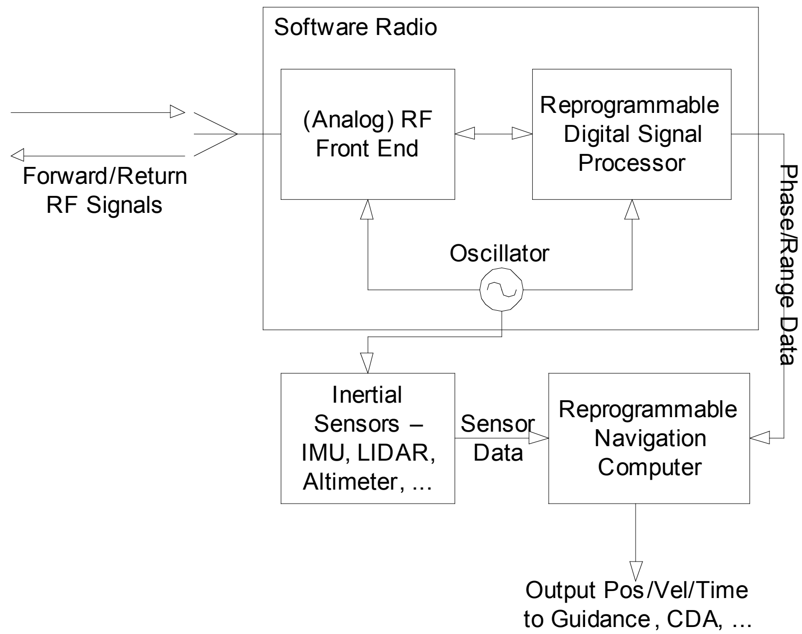
<u>Present Capability:</u> Prototype transceivers exist for low earth orbit applications using GPS signals (not for cislunar environments); Algorithms and conops to enable accurate and fast position determination using two LRS satellites exist.

<u>Technical Approach</u>

This technology initiative will focus on the development of a user transponder/receiver that will be enabled through software defined radio technologies.

- **Formalize future conops and design architectures that define robust methods for implementing a capable, flexible, and evolvable communication/tracking/navigation terminal via a software reprogrammable radio for the lower level communication/tracking functions**
- **Examine the utility of either updating the TDRS transponders to be software derived, or take an existing SDR platform (like the Elektra) and make it TDRS compatible plus LN signal compatible (there is some work to examine the sufficiency of the SN signal at the Moon for the nav use cases that are being envisioned).**
- **Perform the technology development to adapt an existing transponder**
- **Perform the integration with the other sensors and the nav computer that will be interfaced**

High Level Block Diagram of Integrated Comm-Nav Transceiver



Schedule:

	<u>Timeframe</u>
Concept Development	**FY07**
Prelim. Design	**FY07**
Final Design	**FY08/09**
Fabrication/Testing	**FY10**
Technology Demonstration	**FY11/12**

Navigation and Timing

Advanced Optical Navigation: Autonomous Navigation and Guidance System Technology (ANGST)

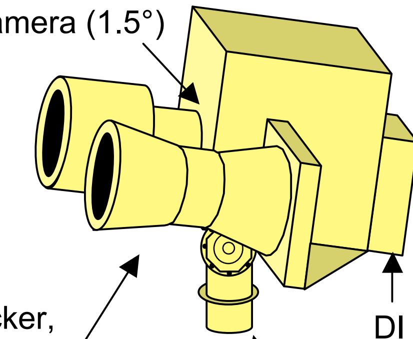
ANGST will provide autonomous and com-link-independent navigation and attitude estimation services, using optical observables for CEV, LLV, rovers. robotic orbiters & landers. The system is intended to alternately operate cooperatively with a radiometric-based navigation subsystem (dependent on Earth, GPS and/or lunar relay links) or independently using "celestial"/optical observations only. The objective will be to develop an integrated HW and SW system, comprised of gimbal-mounted cameras, CPU, accelerometers, & gyro. The system is compact at < .05 m^3, lightweight at 7 kg, and low power, at 7 W.

Current SOA/Practice: Current practice is to provide point nav solutions for each navigation scenario: cis-lunar cruise, orbit insertion and maintenance, rendezvous, landing, ascent, com-free return, surface operations, & attitude maintenance. Often these scenarios utilize dedicated instruments & SW, and often these are viewed as unique developments for each vehicle.

Technical Approach: ANGST is intended to integrate & unify the HW & SW across these functions & scenarios. This effort will:

- **Assess CEV designs that will use many cameras, of various fields, arranged on the vehicle for various functions.**
- **Identify instruments that can serve multiple uses: e.g. Star Tracker/Rendezvous-Wide/Landing-Wide cameras could be the same instrument when integrated into an overall GN&C system and strategy.**
- **Identify and integrate instruments and gimbal mounting (depending on available mounting locations) to reduce the required number of cameras, and reduce mass and cost.**
- **Identify simpler, less expensive & smaller passive optical systems [with back-up active short range sensing (e.g. RADAR)] to support current rendezvous and landing designs that are heavily based on active optical sensing (e.g. LIDAR).**

Notional Concept of a Unified Cx Nav&Guidance Gimbaled Camera Assembly, for optical GN&C



Notional instrument parameters:
Mass: 7 kg; Volume: 32x32x32 cm; Power draw: 7 W

Schedule:

	Timeframe
Design 1st mission scenario	FY08
Develop integ HW + SW system	FY09/10
Field test of integrated system	FY10/11
Demonstration of System	FY11/12

Advanced Networking Technology

Delay (or Disruption)Tolerant Networking Protocol Development

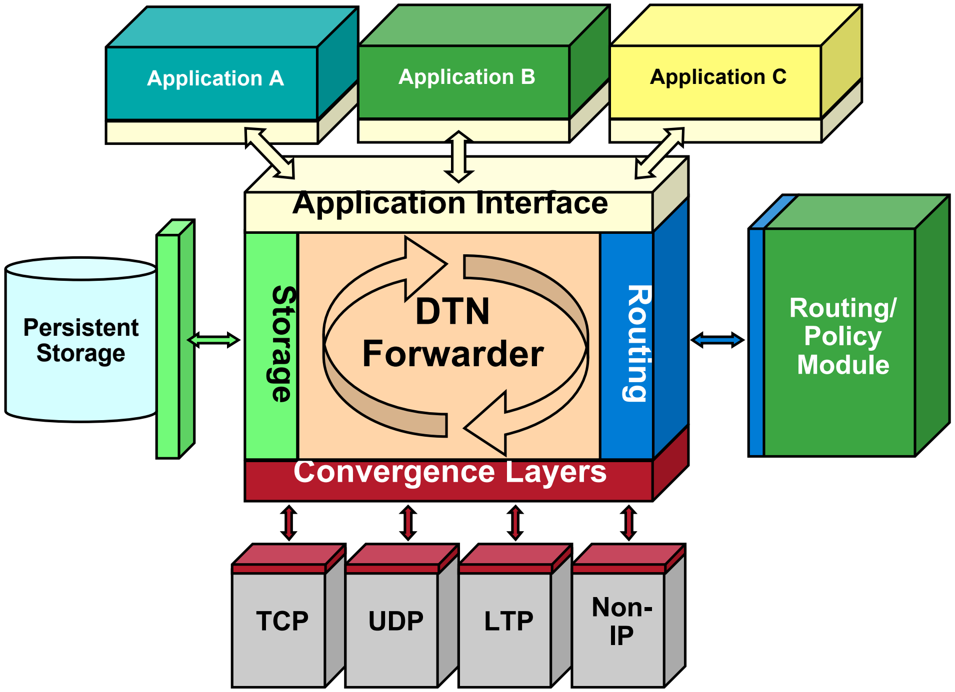
DTN protocols provide for opportunistic use of any available connectivity to move data across harsh communications environments (high delay and BER, intermittent connectivity. DTN is also designed to reduce demands on network resources by integrating storage into the network. This technology initiative will provide a delay tolerant network capability that will enable lunar surface elements and other orbiting assets to be inter-networked across extended distances and provide automated store and forward capabilities for surface assets.

Present Capability: Current capabilities to schedule and provide communications resources and services for assets in deep space are manual intensive and costly.

Technical Approach: A DTN enabled relay satellite will continue to enable critical communications even when not in LOS of surface assets (serving to relay information back to earth). The key needed development is to rapidly advance the DTN technology from its current state (roughly TRL2-3) to TRL6 so that in tandem with IP (currently TRL6-8 in its space application) it is ready for deployment into flight systems. These advances will occur over the next 36-months so that new flight systems that will begin operating in the 2011 timeframe can be confident that the technology is mature. Three principal clusters of activities are planned to advance DTN:

- Specification, Prototyping and Standardization (TRL2 - TRL4)
- Pre-Flight Maturation (TRL5-TRL6)
- Flight Qualification and Deployment (TRL7-TRL9)

DTN Architecture - Layered View



Schedule:

	Timeframe
Specification & Standardization	FY08
Pre-Flight Maturation	FY09
Flight Qualification and Deploy.	FY09/10
Technology Demonstration	FY11/12

Advanced Networking Technology

Surface Wireless Mesh Networking

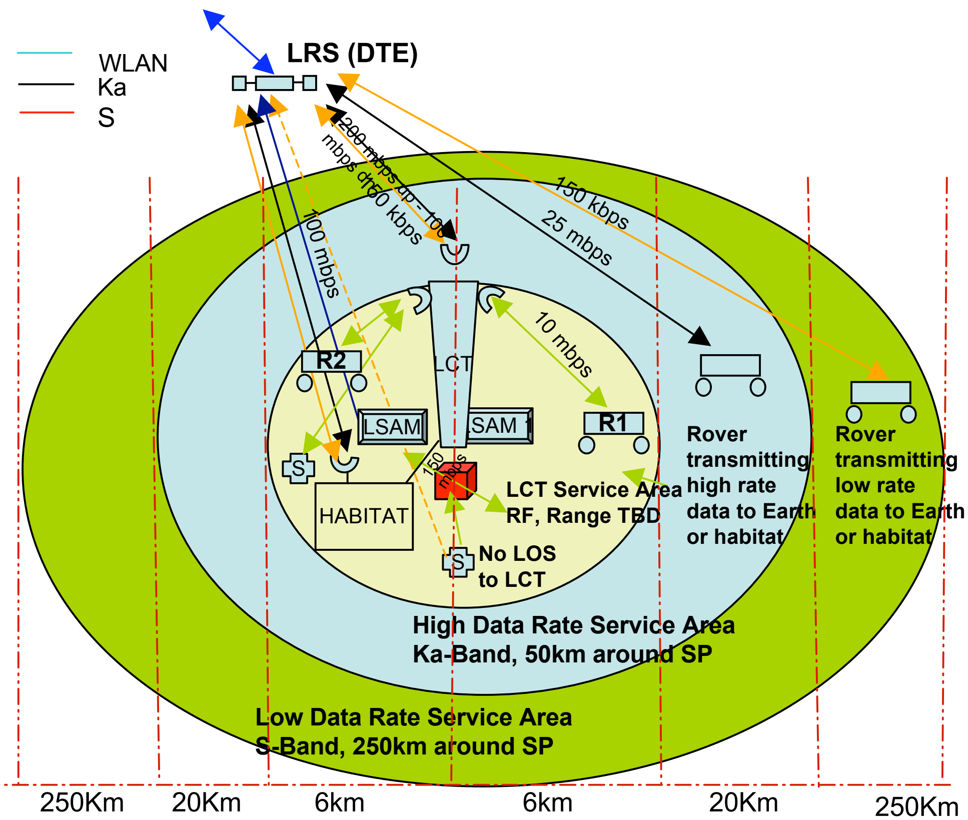
There will be multiple wireless communications links operating simultaneously on the lunar surface; surface network communication links (802.x protocol) and point-to-point and multiple access relay links. This wireless environment presents critical challenges for EVA based communications; manual switching by EVA astronaut is possible but it is desirable to have the ability to automatically detect and switch between the surface 802.x network, LCT and LRS and different link protocols without user intervention and service interruption. The terrestrial equivalent is the concept of Voice Call Continuity (VCC); an automated mechanism for maintaining connection as one moves between WLAN (indoor environment) and the outdoor GSM network. Technology development is needed in the management of multi-link operations across the lunar surface network.

- 802.11 and 802.16-based mesh networking; there is a trend toward convergence for the 802.11 and 802.16 functionalities, both standard are being augmented with mesh network (multi-hop) support, mobility support, QoS. In addition, 802.11n will substantially increase the link throughput. May be premature to select either or both protocols right now but needs a definitive plan to come to a baseline
- Local area access to major network hub such as LCT, LSAM, Habitat
- Seamless handover for highly mobile element
- Range extension between distant surface end-points via mesh networking and LRS relay.

High Performance Router

The LRS and LCT will require space-qualified, high speed routers capable of supporting multiple 100 Mbps network interfaces to terminate high speed RF links (backbone and proximity). The router will need to support processing/routing at a minimum of 350 to 500 Mbps amongst proximity and backbone links.

Lunar Surface Communications Topology



Surface Communications Systems

Surface Wireless Network

The communications hub of the network on the lunar surface will be the lunar communications terminal that will provide both wired and wireless connectivity to major elements on the lunar surface and excursions beyond the line of sight (through the lunar relay satellite). The LCT will provide forward command services, return mission data & telemetry services, 1 & 2-way ranging & Doppler tracking, beacon signaling and in-situ routing. The requirements of the LCT will include the following:

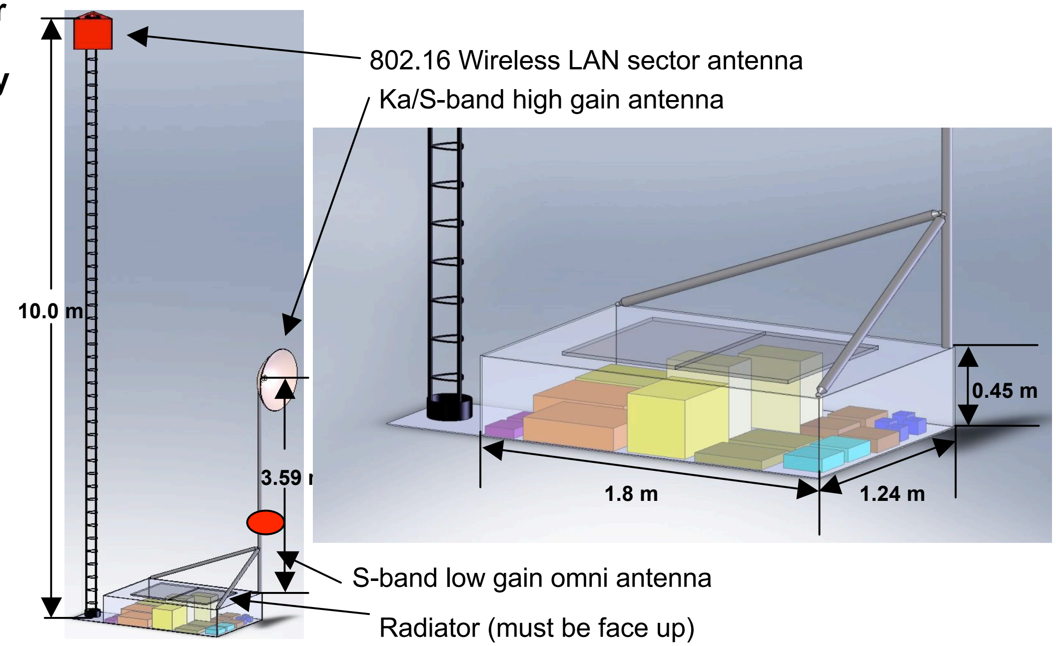
- **Support 15 simultaneous users with an aggregate bandwidth of 80 Mbps at extended ranges to at least 5.6 Km;**
- **Support minimum data rates of 16 Kbps and maximum data rates of 20 Mbps;**
- **Able to convert conventional IP stacks to SN stacks**
- **Support time synchronization service to all surface elements.**

Present Capability: Terrestrial based wireless access points and routers with limited aggregate throughput - designed for static environments. Some development for military applications.

Technical Approach:

- **Tradeoff analysis of high power vs. high user data rates with mesh network**
- **Engineering Development Model and testing**
- **Space Qualifiable Prototype Development**
- **Technology Demonstration**

Notional LCT Design



Schedule:

	Timeframe
Design/Specification	FY08
Engineering Devel. Model	FY09/10
Space Qualifiable Prototype	FY10/11
Technology Demonstration	FY12

Surface Communications Systems

Surface Network Radios

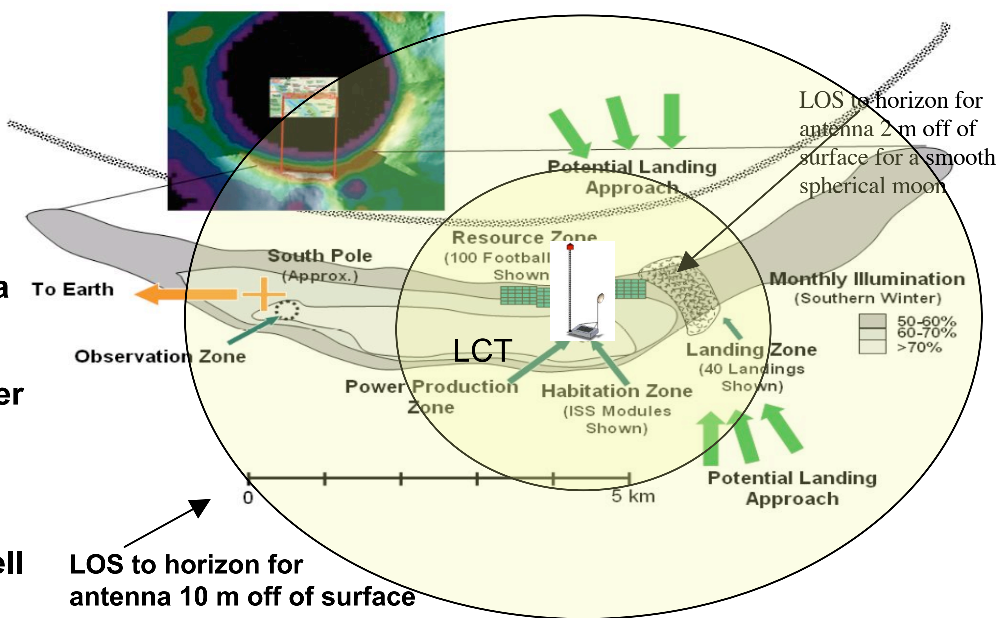
For commonality, C&N designed a set of radios to meet the needs of all other Focus Elements. To minimize non-recurring & recurring unit cost, all radios use common technology & components wherever possible. Three types were defined:

- **Fixed Base User Radio**
  - **Power-efficient mini-LCT sized for five simultaneous users.**
  - **Supports operations remote from LCT anywhere on Moon, e.g. ISRU in crater, nuclear power behind a hill, Sorties, Mobile Lander, man-tended Science cluster.**
  - **Creates WLAN sub-node fully connected to LN providing Ka & S-band antennas to close link to LRS or Earth.**
- **Mobile User Radio for Rovers**
  - **Normal mode in line-of-sight of LCT or Fixed Base, provides high rate data via 802.16e cell phone plus omni S-band 2-way navigation.**
  - **Self-Sufficient mode for remote operations, provides Ka & S-band antennas for Rover to communicate via LRS or Earth, and forward data from EVA Crew.**
- **EVA Suit Radio**
  - **Designed to meet 2 kg and 0.25 W transmit power Suit limits.**
  - **Provides high rate 802.16e cell phone service to LCT or Rover; Rover provides navigation.**
  - **Contingency walk-back scenarios - Supports 8 kbps contingency voice to LRS on S-band as well as 2-way navigation.**

Schedule (Does not include EVA Radio)

	Timeframe
Design/Specification	FY08
Engineering Devel. Model	FY09/10
Space Qualifiable Prototype	FY10/11
Technology Demonstration	FY12

Line-of-sight Coverage From LCT
For LAN Radios (smooth surface assumed)



LOS to horizon for antenna 10 m off of surface for a smooth spherical moon

Surface Communications Systems

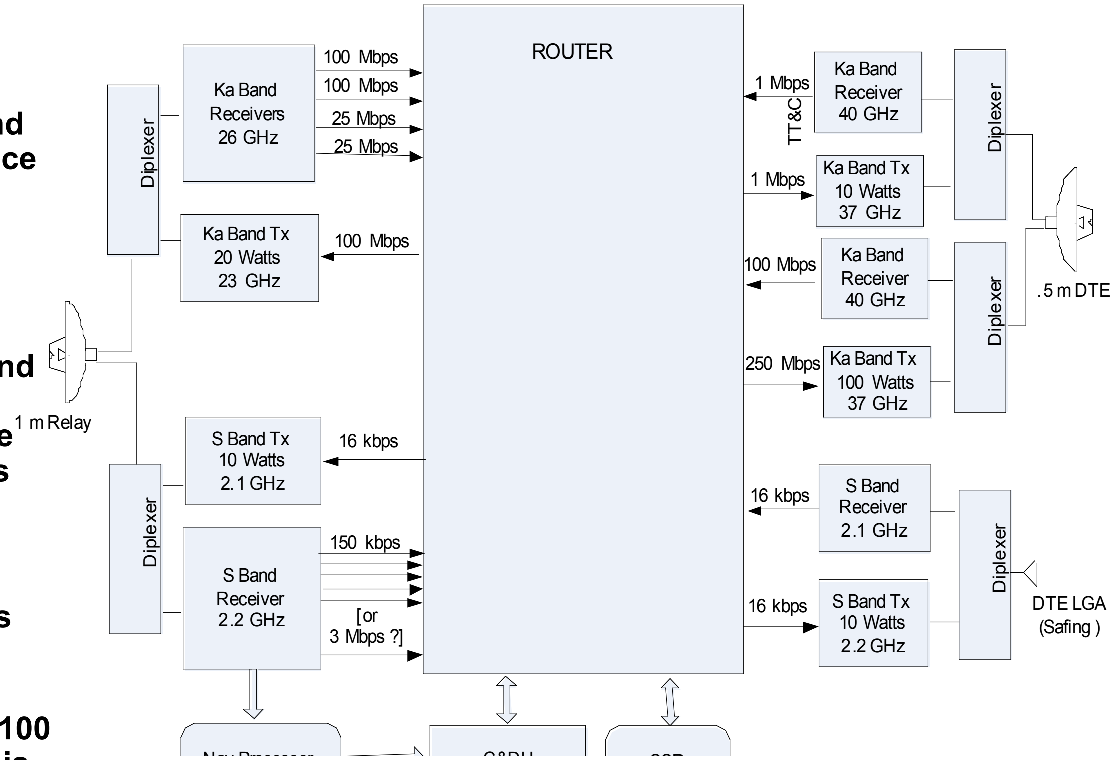
High Data Rate Modem

The LCT and LRS will serve as major ‘network access points’ for multiplexing and routing data within the lunar vicinity and between the moon and earth. The LRS and LCT will need to provide service to multiple surface assets simultaneously, each having different data volume requirements depending on the operational scenario. Based on current traffic models, the LRS, LCT and Habitat need to be capable of processing 100 Mbps communications links from the lunar surface to and from earth. There are currently 100 Mbps modulators but the technology need is for a space qualified decoder capable of supporting 100 Mbps data rates at QPSK.

<u>Present Capability</u>: 100 Mbps modulator on LRO; ESA has developed 150 Mbps modulator; no high speed demodulator exists at the needed 100 Mbps data rates

<u>Technical Approach</u>: This effort will focus on the development of a high speed encoder to support 100 mbs data rates from the LRS, LCT and Habitat. This component would be deployed in each of these major subsystems. Major activities include:

- **Design/Specification**
- **Engineering Development Model**
- **Develop Space Qualifiable Prototype**
- **Conduct Technology Demonstration**



Schedule:

	<u>Timeframe</u>
Design/Specification	**FY08**
Engineering Devel. Model	**FY09/10**
Space Qualifiable Prototype	**FY10/11**
Technology Demonstration	**FY12**

Integrated Wireless Technology

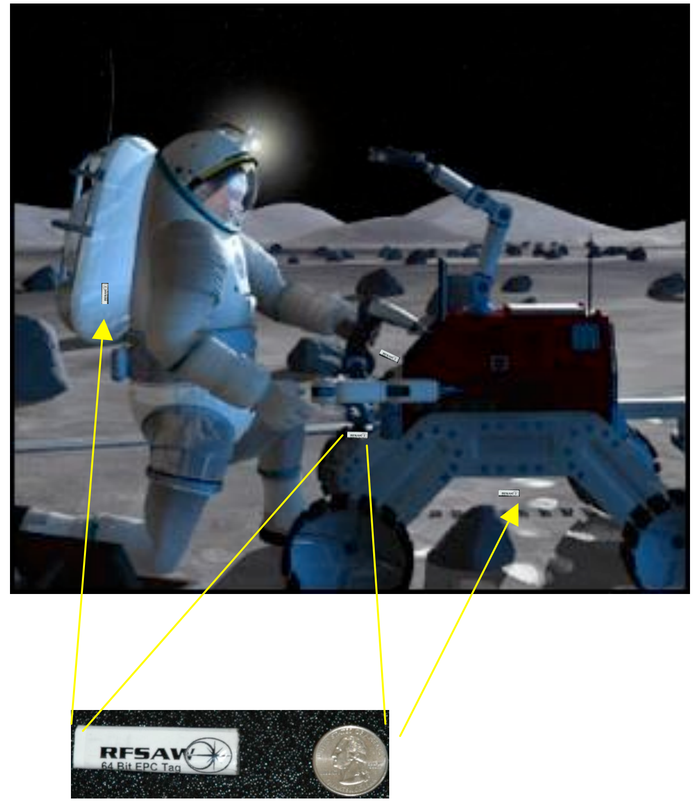
Combined RFID + Passive, Wireless Sensor Systems

Current inventory management schemes on the International Space Station are based on optical barcode technologies which can be very labor intensive. Current ISS and SSO sensors entail too much wire mass or require batteries. Specific technology needs include:

- **Interrogator that reads RFID tags for inventory management & also reads passive wireless sensors. Fundamental physics of interrogation are very similar, so SDR for interrogator should reduce cost & permit re-use.**
- **Need to assure interoperability, both from a spectrum management perspective with international partners, as well as inventory management commonality between multiple Cx elements.**
- **Maturation of RFID standards and related technologies – SDR approach should reduce risk.**
- **Integrate RFID+sensor functionality to reduce cost & promote re-use/sparing to save crew time (cost).**
- **Use passive, wireless sensors that permit greater situational awareness (safety) by permitting more sensors, while reducing wire mass and battery use (crew time, safety, cert cost).**

High probability applications:

- **Inventory management**
  - **Crew supplies**
  - **Food, medicine**
- **Real-Time Localization: EVA tools, equipment**
- **Monitoring/verifying inter-habitat supply transfers**
- **"Boneyard" inventory: Real-time access to surplus parts**



Example: passive COTS tag with 64 bit ID code, temperature and range telemetry

- **Smart tag and other potential applications**
  - **Monitor tool exposure limits and provide warnings (e.g., temperature extremes, shocks)**
  - **Storage of calibration information on sensors, LRUs**
  - **Passive tag tracking**
  - **Potential to enhance or enable automation**

NASA Implementation Philosophy

- The US will build the transportation infrastructure and initial communication & navigation and initial EVA
- Open Architecture: NASA will welcome external development of lunar surface infrastructure

- The US will perform early demonstrations to encourage subsequent development
- External parallel development of NASA developed capabilities will be welcomed