Emulating the Lunar Communications and Navigation Architecture in the Analog Mission Environment

Opportunities for International Partnering

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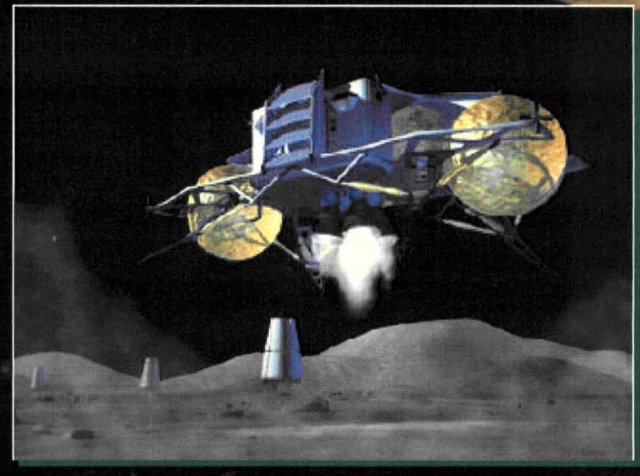
NASA Implementation Philosophy

- 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

Source: Exploration Strategy and Architecture, *Shana Dale*, 2nd Space Exploration Conference , December 4, 2006

Open Architecture: Infrastructure Open for Potential External Cooperation

- **Lander and ascent vehicle**
- **EVA system**
  - CEV and Initial Surface capability
  - Long duration surface suit
- **Power**
  - Basic power
  - Augmented
- **Habitation**
- **Mobility**
  - Basic rover
  - Pressurized rover
  - Other; mules, regolith moving, module unloading
- **Navigation and Communication**
  - Basic mission support
  - Augmented
  - High bandwidth
- **ISRU**
  - Characterization
  - Demos
  - Production

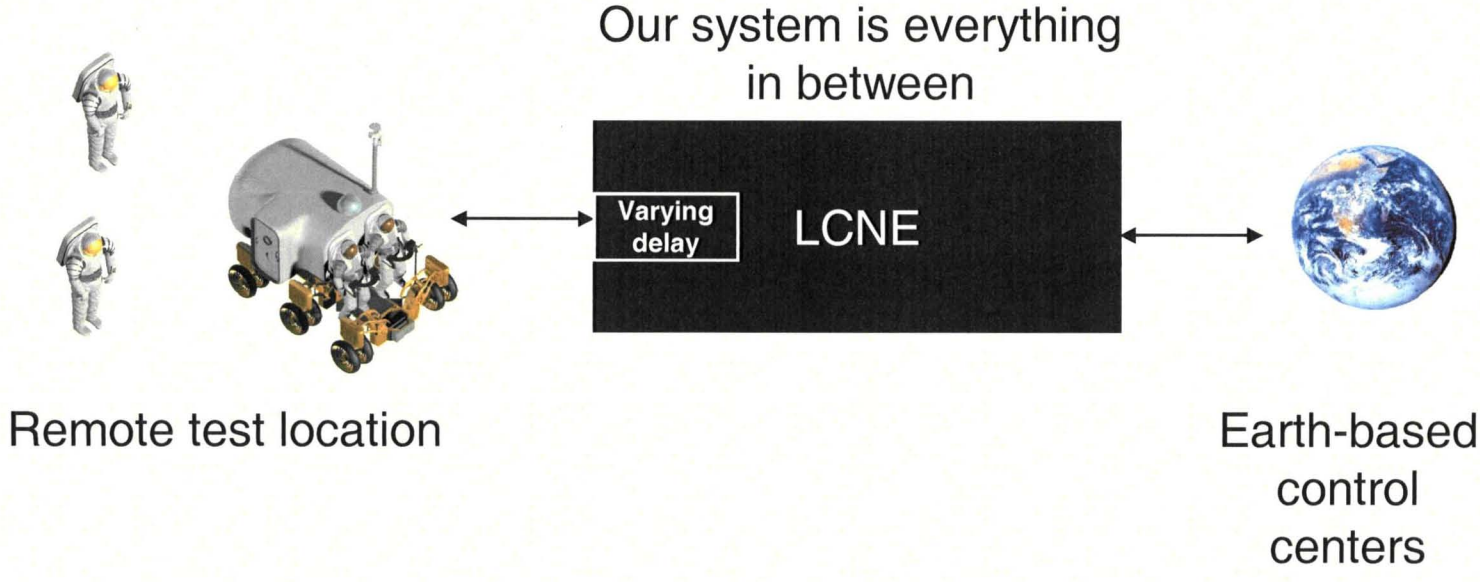
- **Robotic Missions**
  - LRO- Remote sensing and map development
  - Basic environmental data
  - Flight system validation (Descent and landing)
  - Lander
  - Small sats
  - Rovers
  - Instrumentation
  - Materials identification and characterization for ISRU
  - ISRU demonstration

From a lunar comm emulation perspective:
In concert with this Agency philosophy, we manage the field emulation of basic communication and navigation capability for the Analogs, but seek partnering on augmented comm concepts

** US/NASA Developed hardware

Emulating the SCaN/LSS Lunar Architecture

- A Lunar Comm and Network Emulator (LCNE)
  - **Complies with Agency plans for architecture buildup**
  - "Mimics the function" of the Lunar Network under development from "boots on the ground" all the way back to NASA
  - Includes surface comm infrastructure, aggregate backhauls, network tunnels, security plans, protocols to tie link assets back to NASA

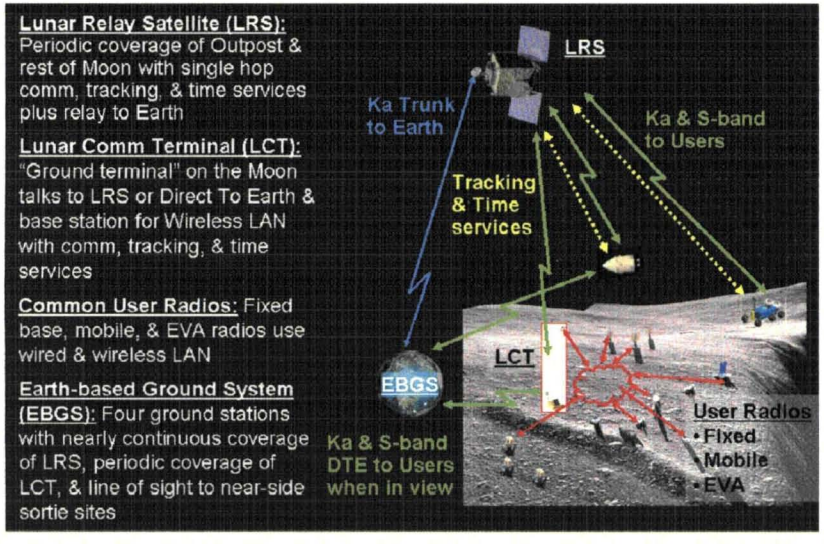


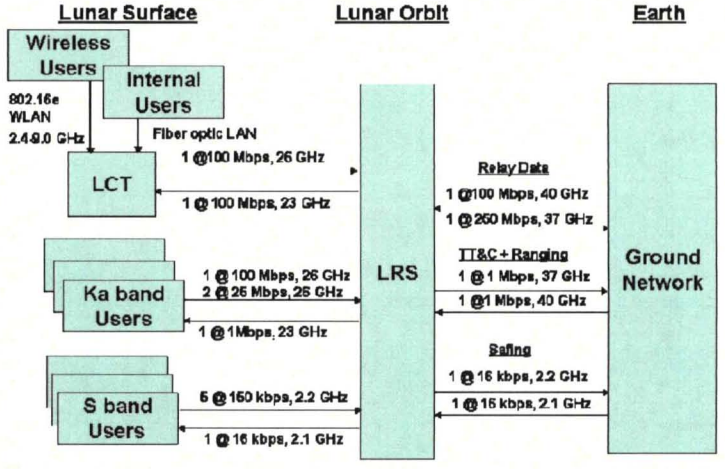
Emulating the SCaN/CxLSS Lunar architecture

- **NASA's Lunar Comm and Network Emulator (LCNE)**
  - Is a real-time, **production-level** system analog **teams count on to conduct their investigations**
  - Is a means for analog teams to test their hardware, software and operations concepts with planned lunar comm conditions, **aka "feel it"**
  - Provides a mechanism for teams to **"dry-run" their systems** for weeks at the home center prior to fielding the technology
  - Provides **incremental fidelity** at all possible levels (architecture, protocols, radio links, delays, etc)
  - Can **replicate the function of many different lunar network architectures**, day to day, week to week, etc
  - Allows for **performance measurement** of large integrated lunar scenarios
  - **Provides feedback** to SCaN architects, and may help expose "gotchas" in the architecture through ongoing testing
  - Has the flexibility to allow Commercial and International partner concepts and components to be folded-in and included for validation and verification

What we emulate in the field

- Lunar comm/nav architectures that are relevant to the Analog mission planned **(i.e., 1-day versus 3-day versus 14-day sorties, etc)**
- **Realistic (not too high, not too low) useable bandwidth** for users of the network
- **Candidate network protocols and standards**
- **Use of promising RF spectrum for the lunar environment**
- **Mobile lunar comm/nav assets** and their mission-oriented functions
- **Fixed/stationary lunar comm/nav assets**
- *Bottom line:* ***NASA SCaN Program-compliant architectures*** *so users can "feel" what the comm/nav will feel like on the moon*

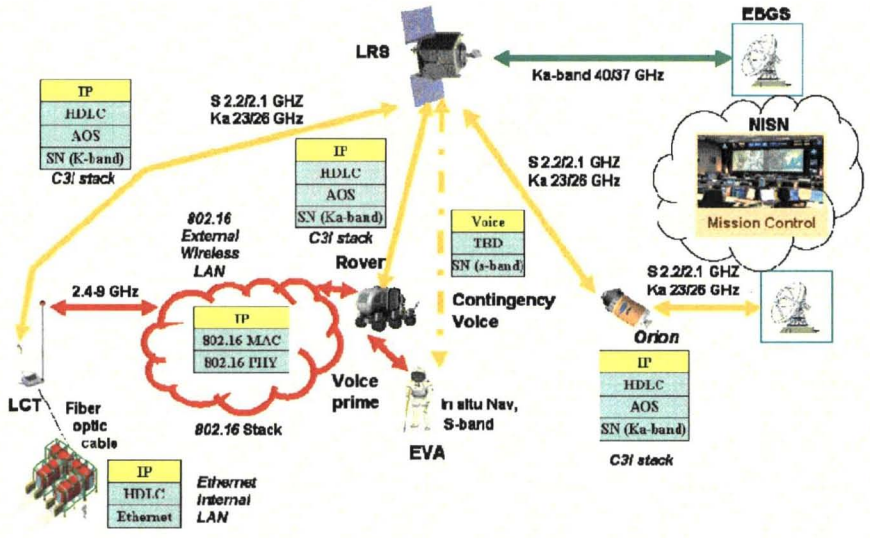


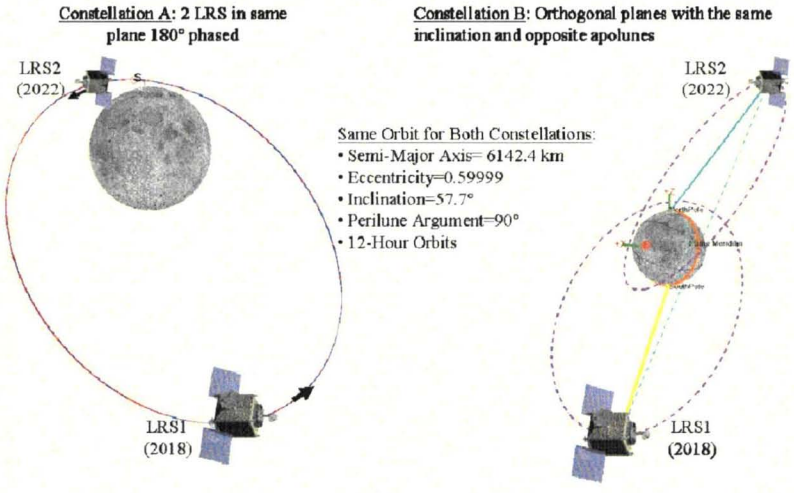


What we emulate in the field

- Emerging operations concepts (like "which elements have which types of radios" and "who can talk to who" and "when"?)
- Are there comm operations scenarios that can conserve rover power significantly?
- What are the effects of using just one Lunar Relay Satellite? No relay satellites?
- What happens if communication is lost for brief, and lengthy periods of time?
- Mars-forward: what are the impacts of Mars delay on human interaction with Earth?

These are big architecture-driving questions we're answering in the analog venue

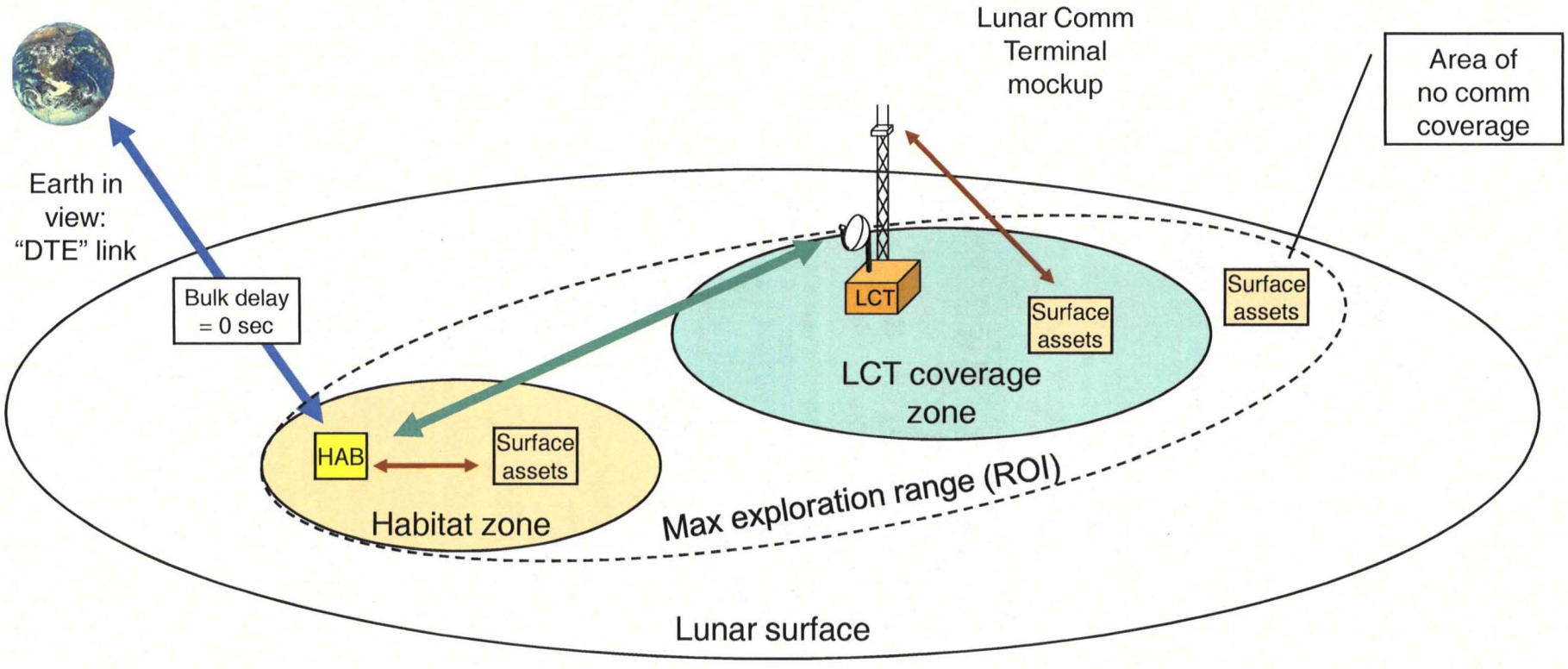




Example

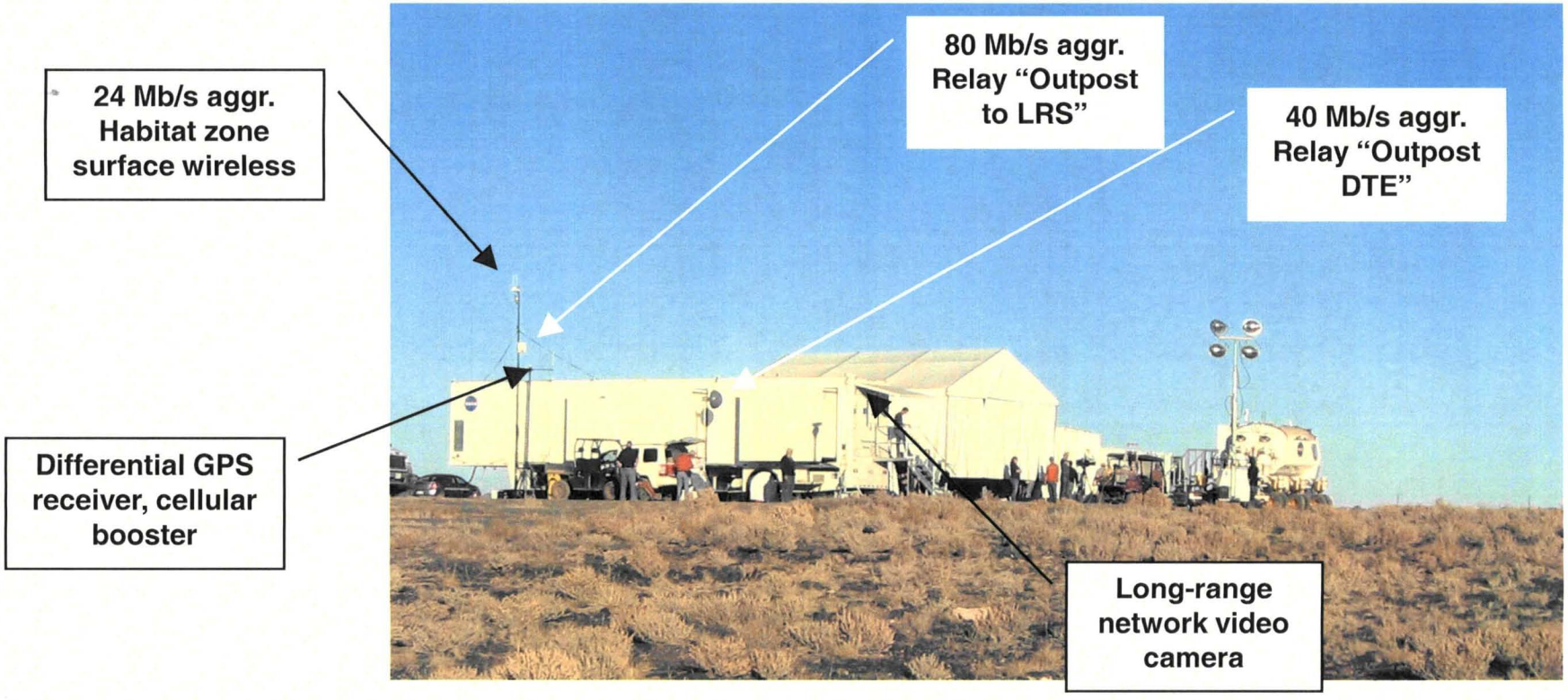
September 2008, D-RATS 3-day lunar sortie, Mission with LER

Communication modeled the use of a Lunar Comm Terminal (LCT) providing coverage during traverses Up to 10km from the outpost



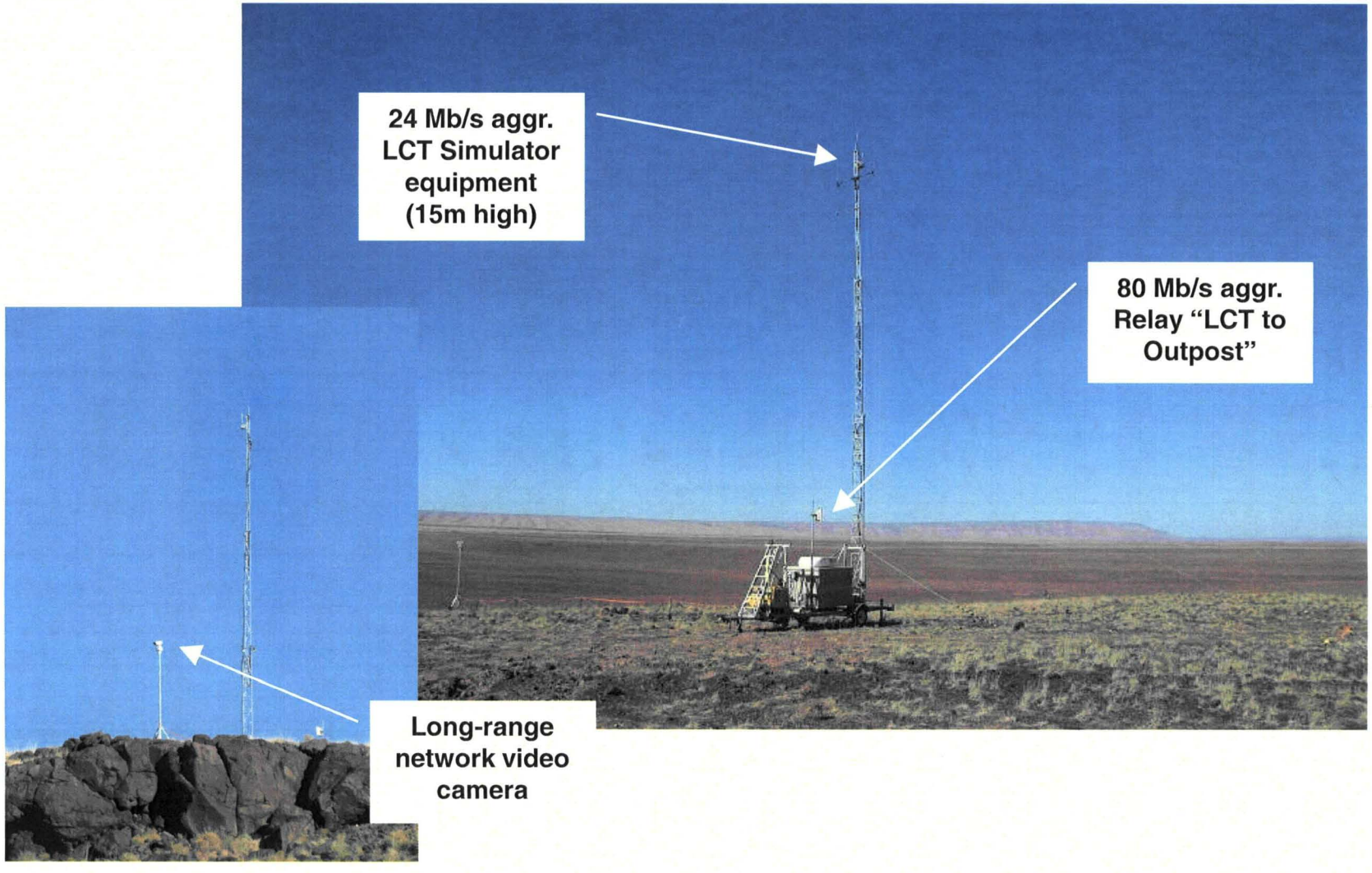
LCNE configuration for BPLF/AZ, Oct '08

- **Lunar Outpost (at the Analog)**
  - "Hub" for all communications and networking
  - Network security assets
  - Network measurement assets

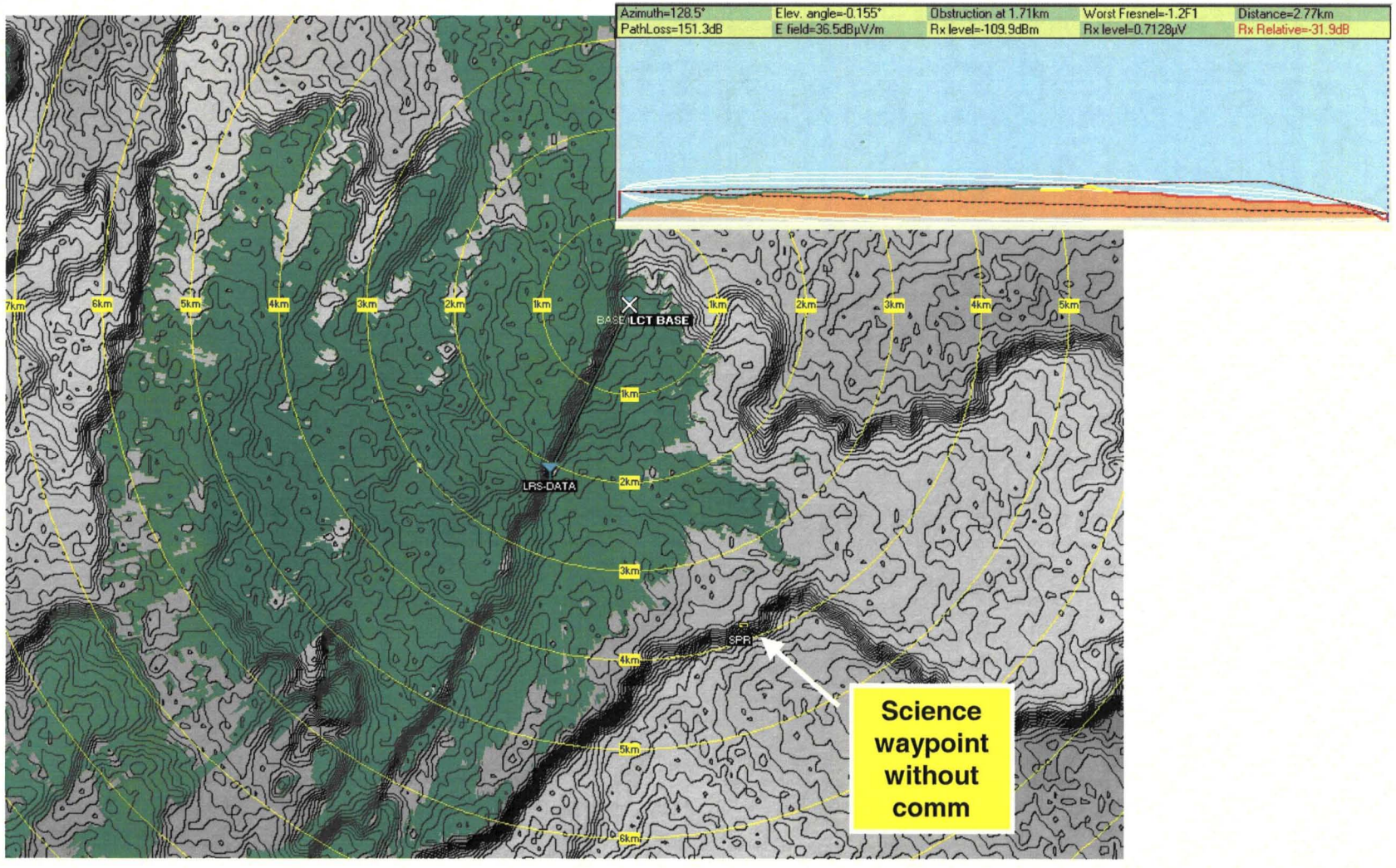


LCNE configuration for BPLF/AZ, Oct '08

Lunar Comm Terminal (LCT) for Oct test



Predicting LOS on the surface during traverses

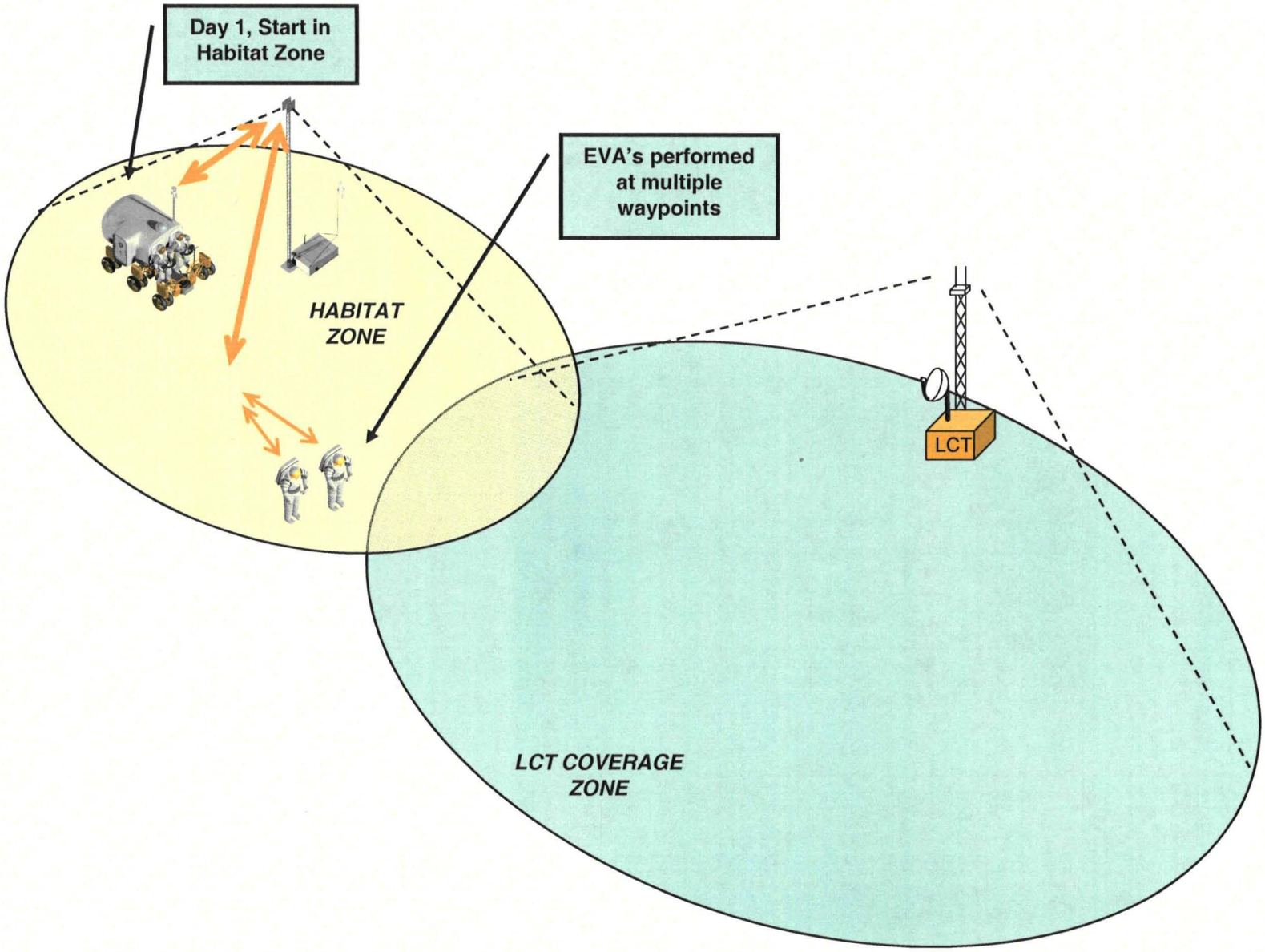


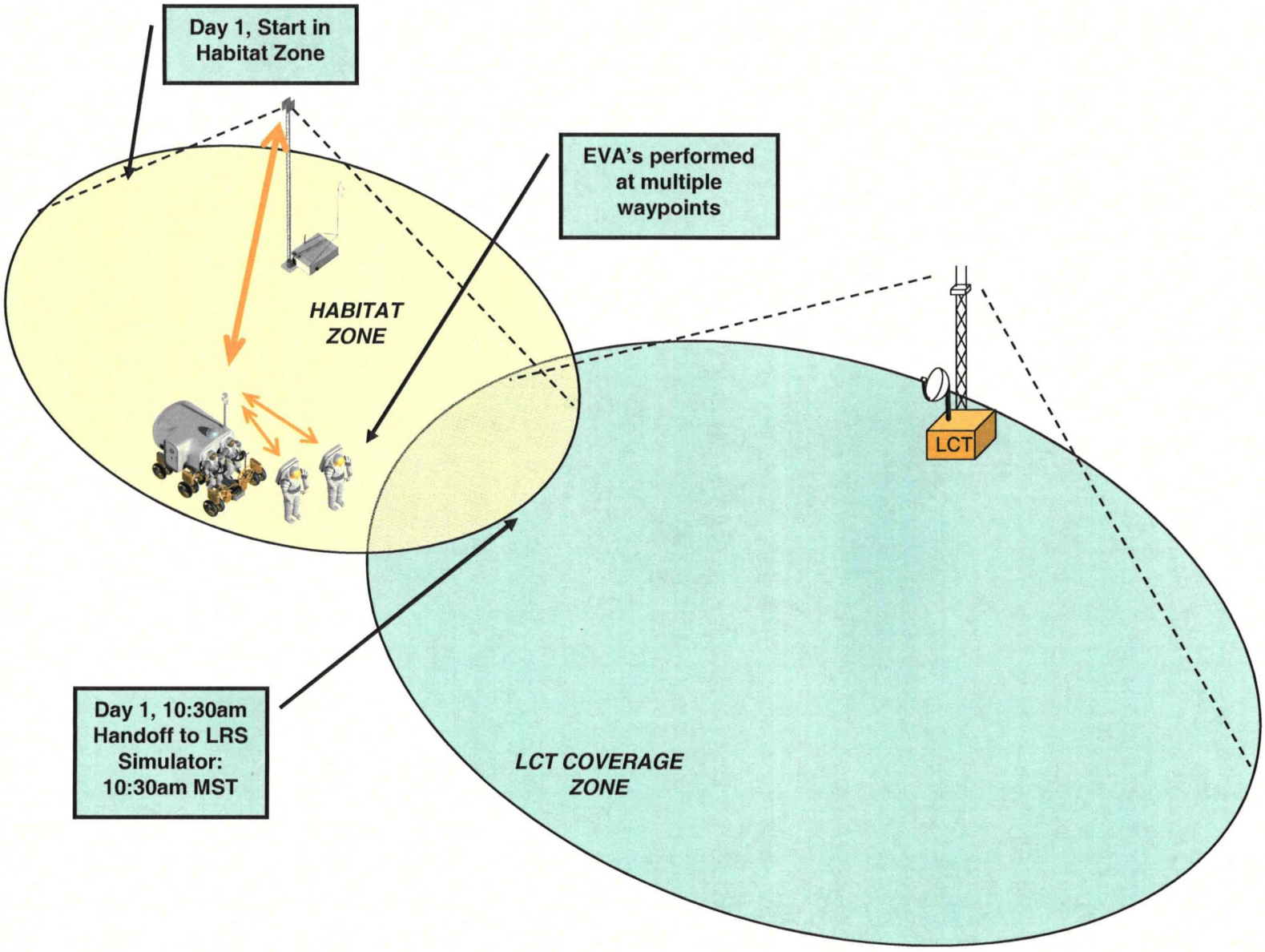
Real-time mapping and coverage prediction are essential to predict and report loss of comm scenarios during traverses

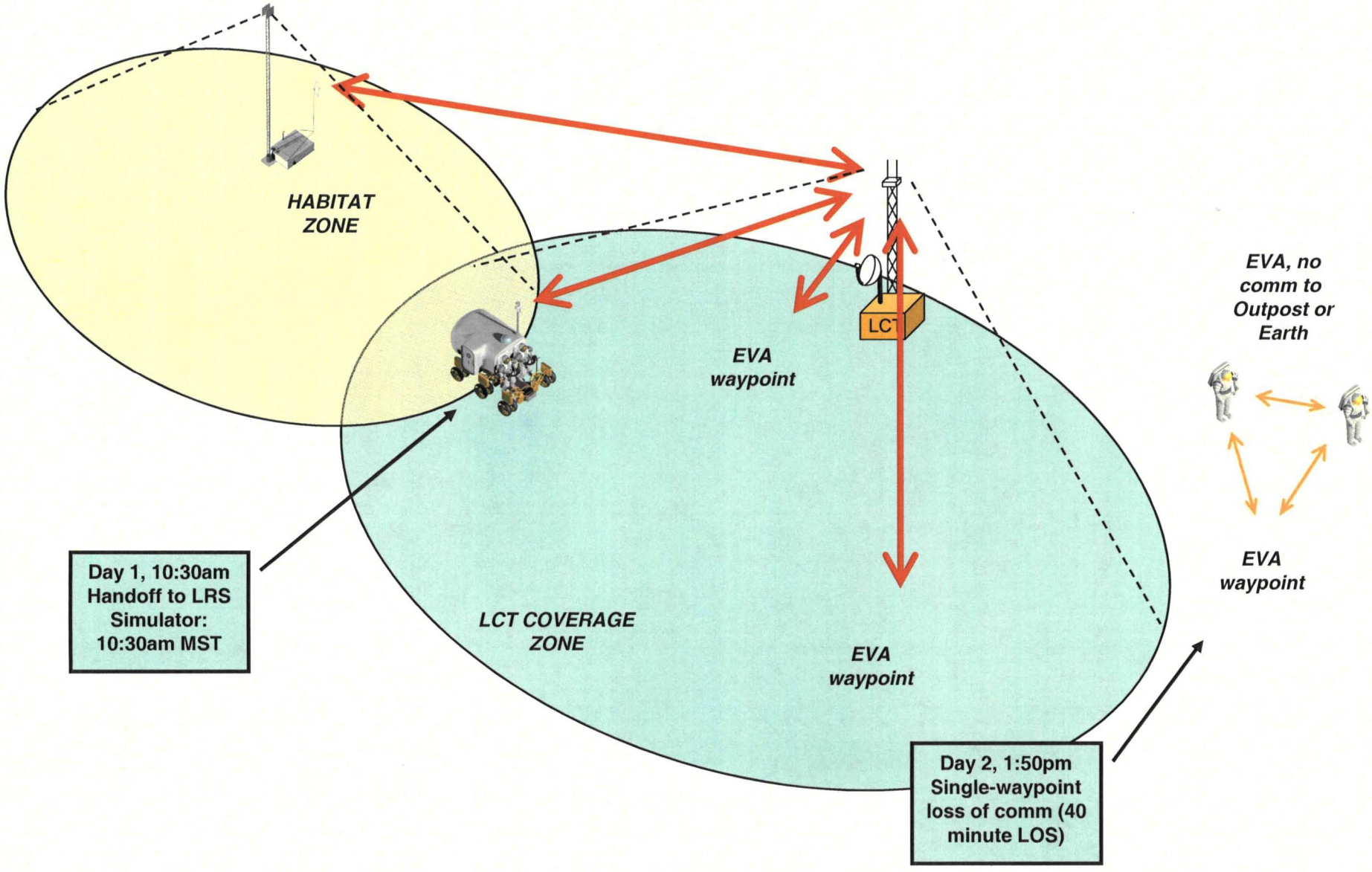
Days 1 and 2

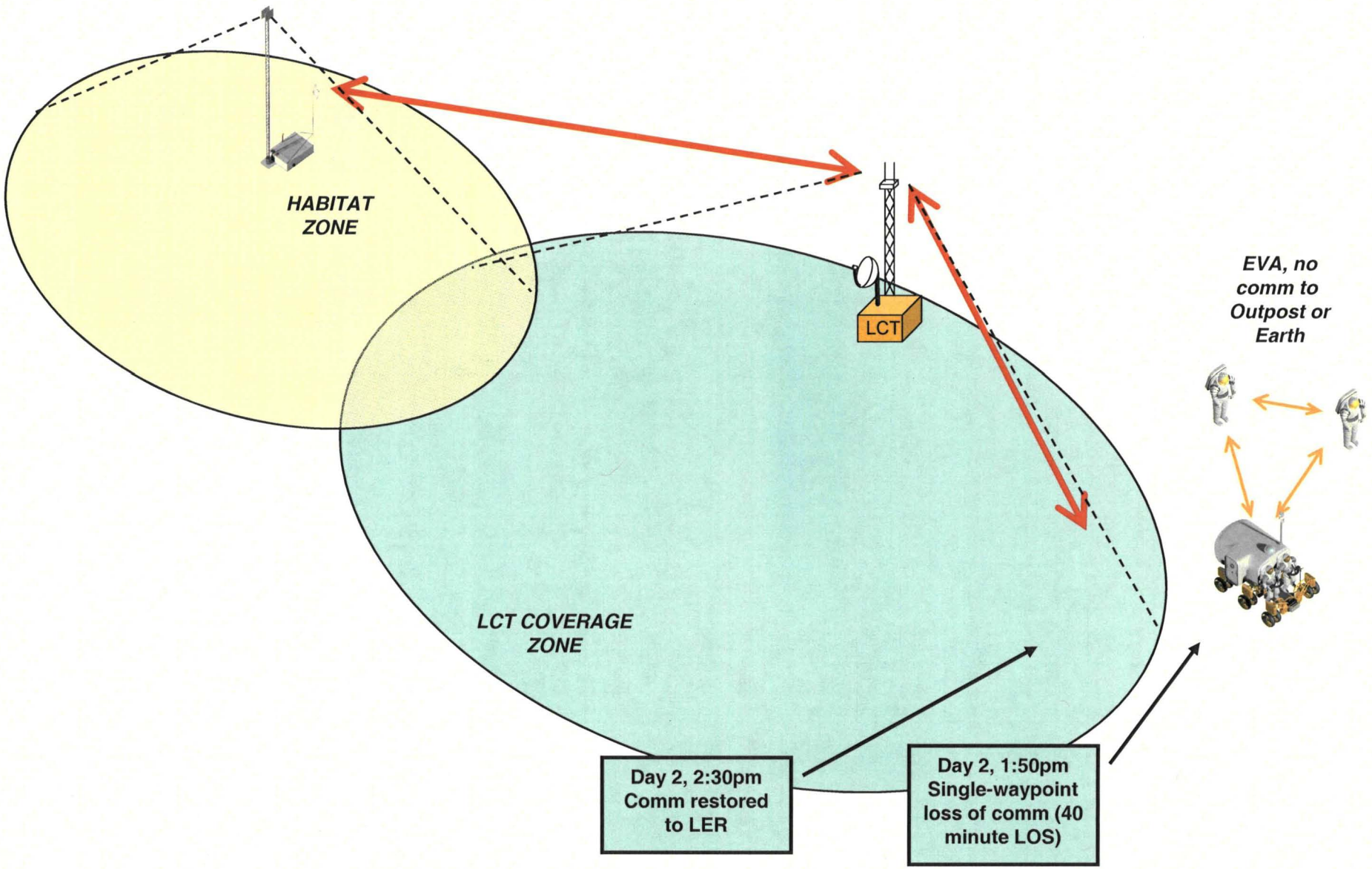
LER-3 Day traverse, BPLF

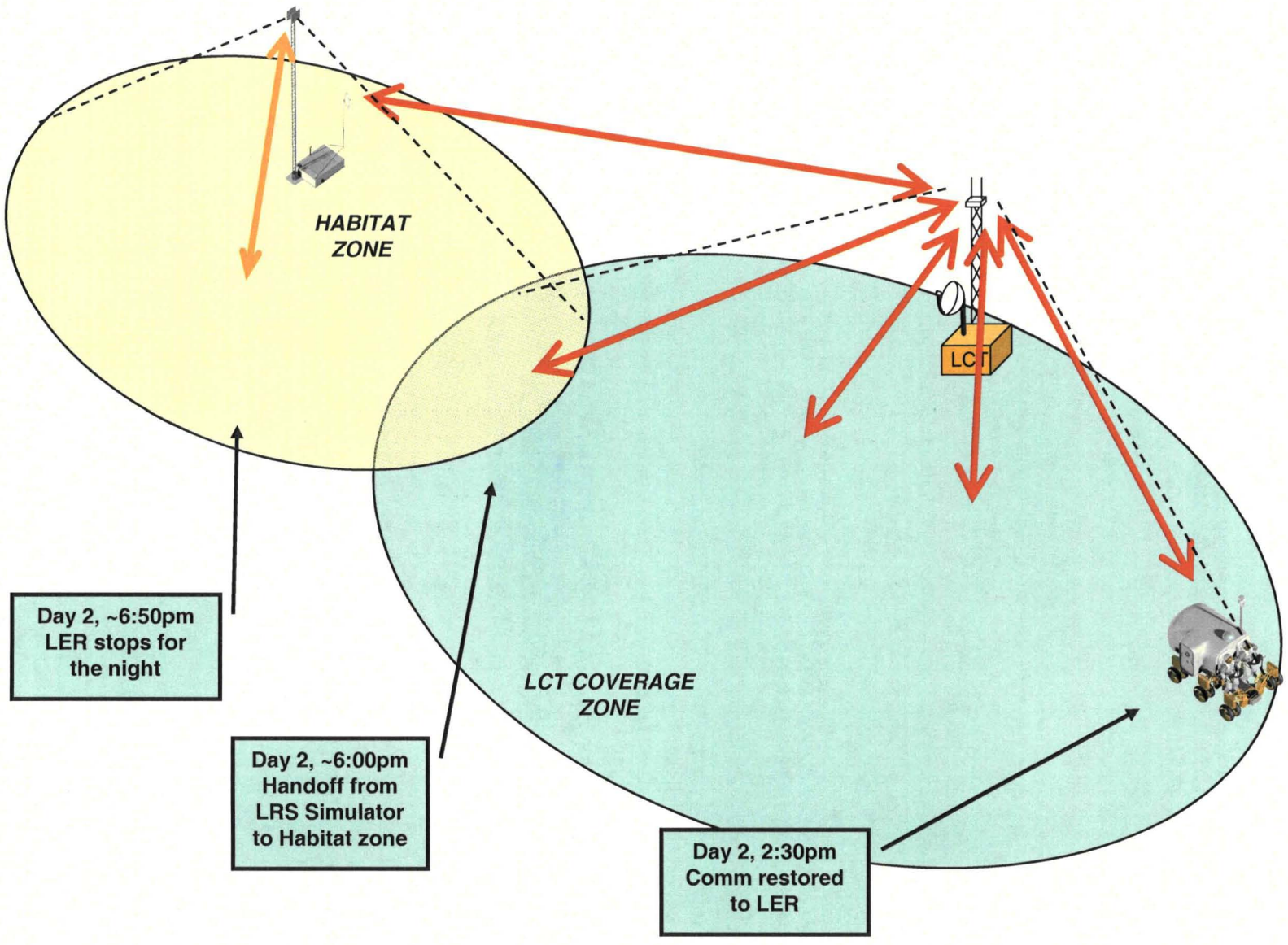
LER 3-day traverse, Communications Handoff




Day 1, Start in Habitat Zone
EVA's performed at multiple waypoints
HABITAT ZONE
LCT
Day 1, 10:30am Handoff to LRS Simulator: 10:30am MST
LCT COVERAGE ZONE


HABITAT ZONE
LCT
EVA waypoint
EVA, no comm to Outpost or Earth
EVA waypoint
LCT COVERAGE ZONE
EVA waypoint
Day 1, 10:30am Handoff to LRS Simulator: 10:30am MST
Day 2, 1:50pm Single-waypoint loss of comm (40 minute LOS)


HABITAT ZONE
LCT
LCT COVERAGE ZONE
EVA, no comm to Outpost or Earth
Day 2, 2:30pm Comm restored to LER
Day 2, 1:50pm Single-waypoint loss of comm (40 minute LOS)


HABITAT
ZONE
LCT
LCT COVERAGE
ZONE
Day 2, ~6:50pm
LER stops for
the night
Day 2, ~6:00pm
Handoff from
LRS Simulator
to Habitat zone
Day 2, 2:30pm
Comm restored
to LER

Our core objectives for RATS '09

- **Evaluate the notion of a Portable Communication Terminal (PCT) concept for surface communications between two LER rovers on extended traverses**
  - Simulate various constrained comm conditions (single LRS coverage scenario, no comm, delayed comm)
  - Use RF propagation/prediction tools to select best location for PCT based on traverse paths and science waypoints.
  - Move PCT periodically (every couple days) during long traverses to illuminate new sets of science waypoints
  - Record performance data, evaluate impacts of the various comm scenarios
- **Examine the operational benefits of employing a PUP with communications to extend comm coverage in addition to the PCT**
- **Evaluate full-duplex NASA C3I-compliant VoIP communications with EVA crew and IVA rover crews**

Analog activities currently engaged

- **For ESMD**
  - Desert RATS 2009 sortie
    - 14-day lunar mission simulation, Sept '09, Black Point Lava Flow, AZ
    - 2 LER rovers, 2-tri-athletes, 4-suited subjects, CAPCOM, science backroom
    - Deploy LCNE characteristic of lunar environment for this type of mission
    - Ensure communications for D-RATS are "SCaN-compliant" in function
  - Robotic precursor (aka "recon) mission
    - 14-day mission, June '09, Black Point Lava Flow, AZ
    - Deploy LCNE for rover teams so September crew and mobility personnel at NASA centers can "recon" promising areas of interest prior to "landing on the surface"
    - Ensure communications for robotic recon are "SCaN-compliant" in function
  - November ISRU testing, Hawaii
    - (Similar to Nov '08 test) Consult ISRU Project Management in comm/nav architecture plans, encourage SCaN compliance of comm/nav architecture within project budget
- **For SMD**
  - Pavilion Lake Research Project (PLRP)
    - 14-day mission, June '09, Pavilion Lake, B.C., Canada
    - Engineer, deploy and operate entry-level LCNE for researchers studying microbialites
    - Fold-in emerging lunar comm operations concepts into PLRP
    - Ensure communications for PLRP are "SCaN-compliant" in function

Partnering opportunities in Analog Comm/Nav

- **CSA with NASA involvement:**
  - Consider steering CSA-led analog comm/nav architectures towards compliance with the NASA/SCaN planned base architecture
    - Helps ensure future compatibility
    - Trains users of the infrastructure on "what the lunar network will feel like"
    - Include NASA Analog Comm/Nav personnel in architecture planning, concepts and designs for CSA-led analogs
  - Welcome promising NASA comm/nav elements to operate in concert with CSA-led comm/nav infrastructure at CSA analogs (HMP, Hawaii, etc)
- **NASA with CSA involvement:**
  - Identify promising comm/nav opportunities for CSA participation at NASA analogs, referencing NASA "Open Architecture" framework
  - Coordinate the inclusion of promising CSA comm/nav technologies and systems in the NASA-led analogs (D-RATS, NEEMO, etc)

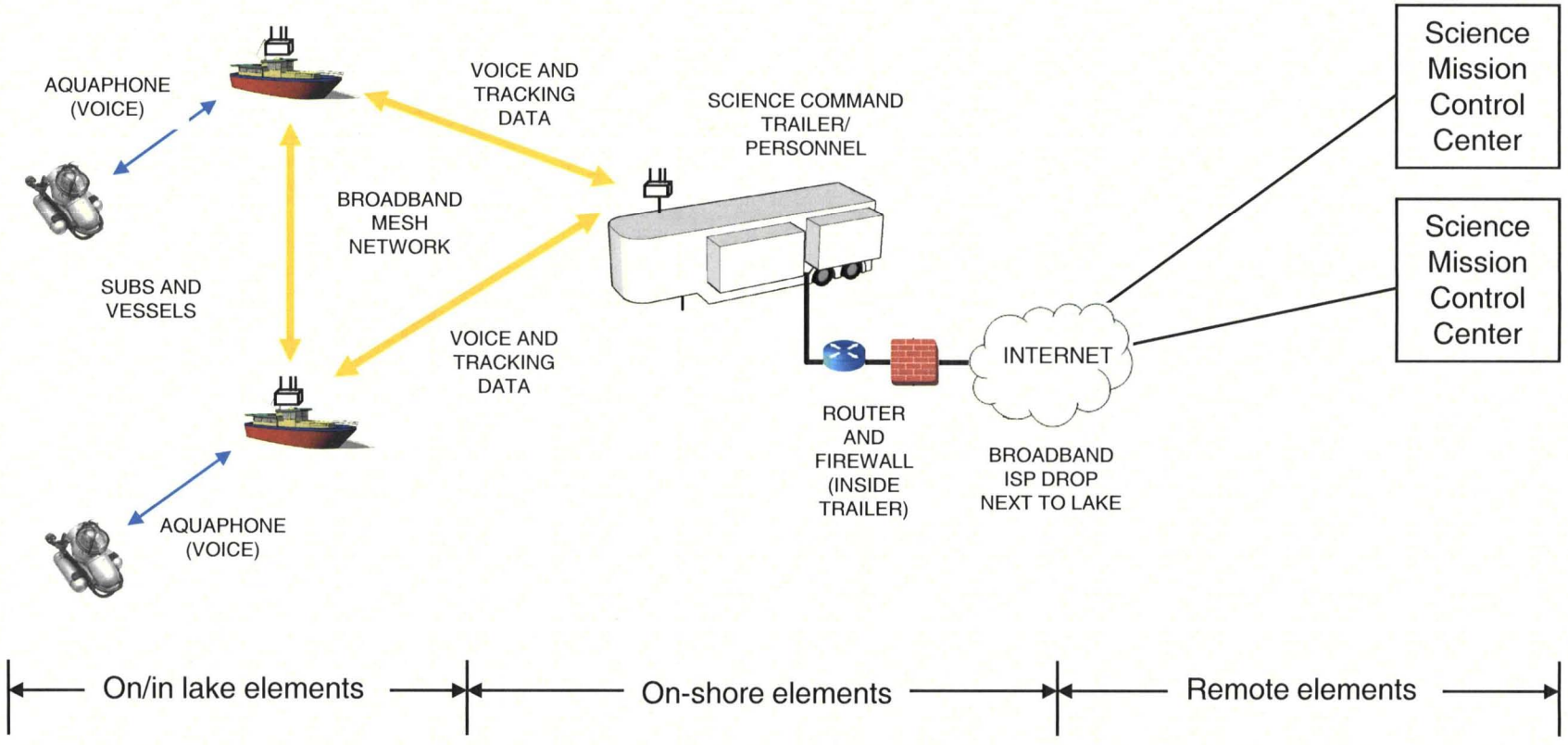
Working together in these early phases of planning benefits everyone in the long run.

We are much stronger together than we are alone!

Backup

PLRP '09 Communications

Pavilion Lake communications plan, Comm/Network Overview

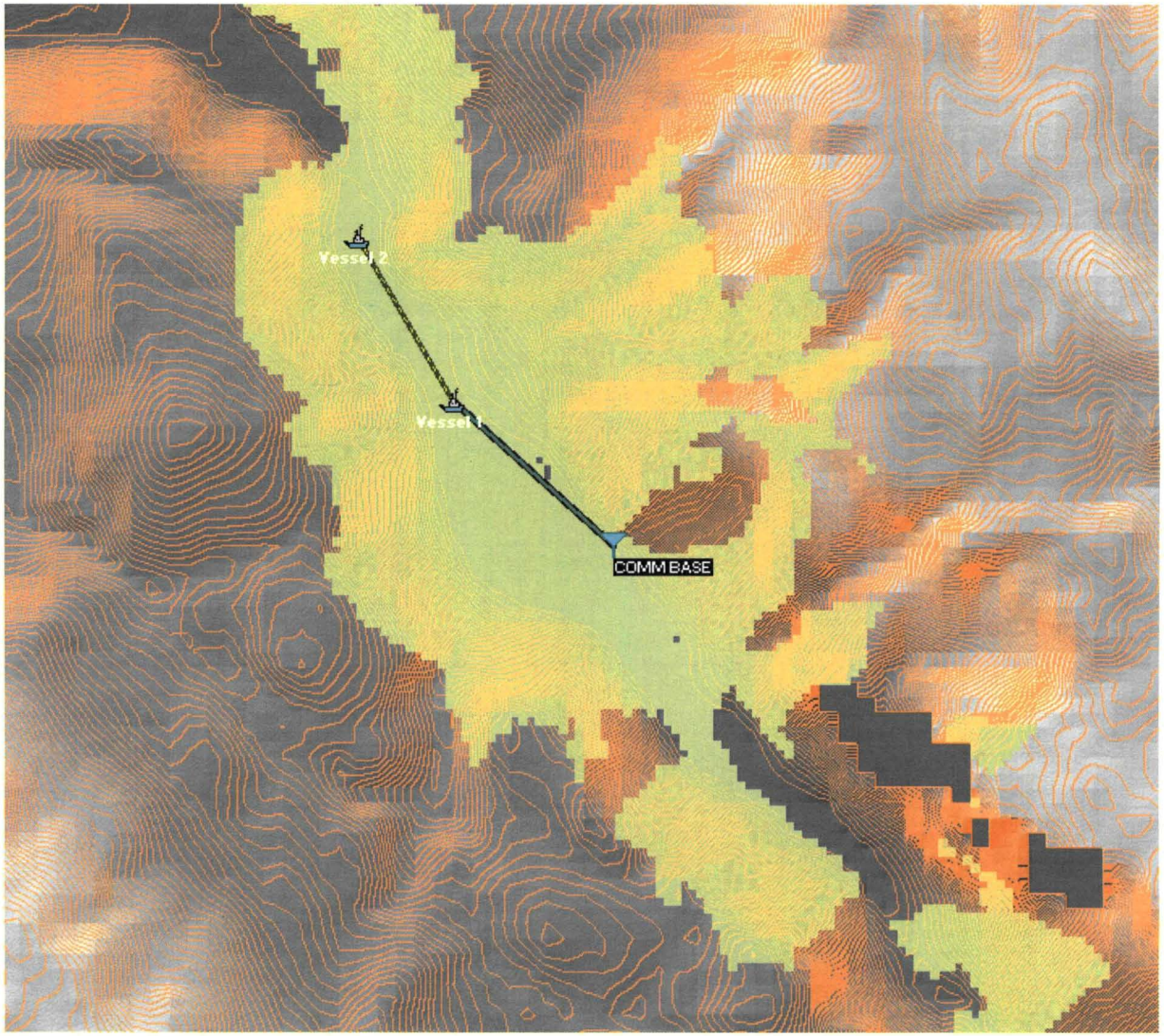


PLRP '09 Communications

Pavilion Lake communications plan
Illustration – Extending mesh coverage to the north

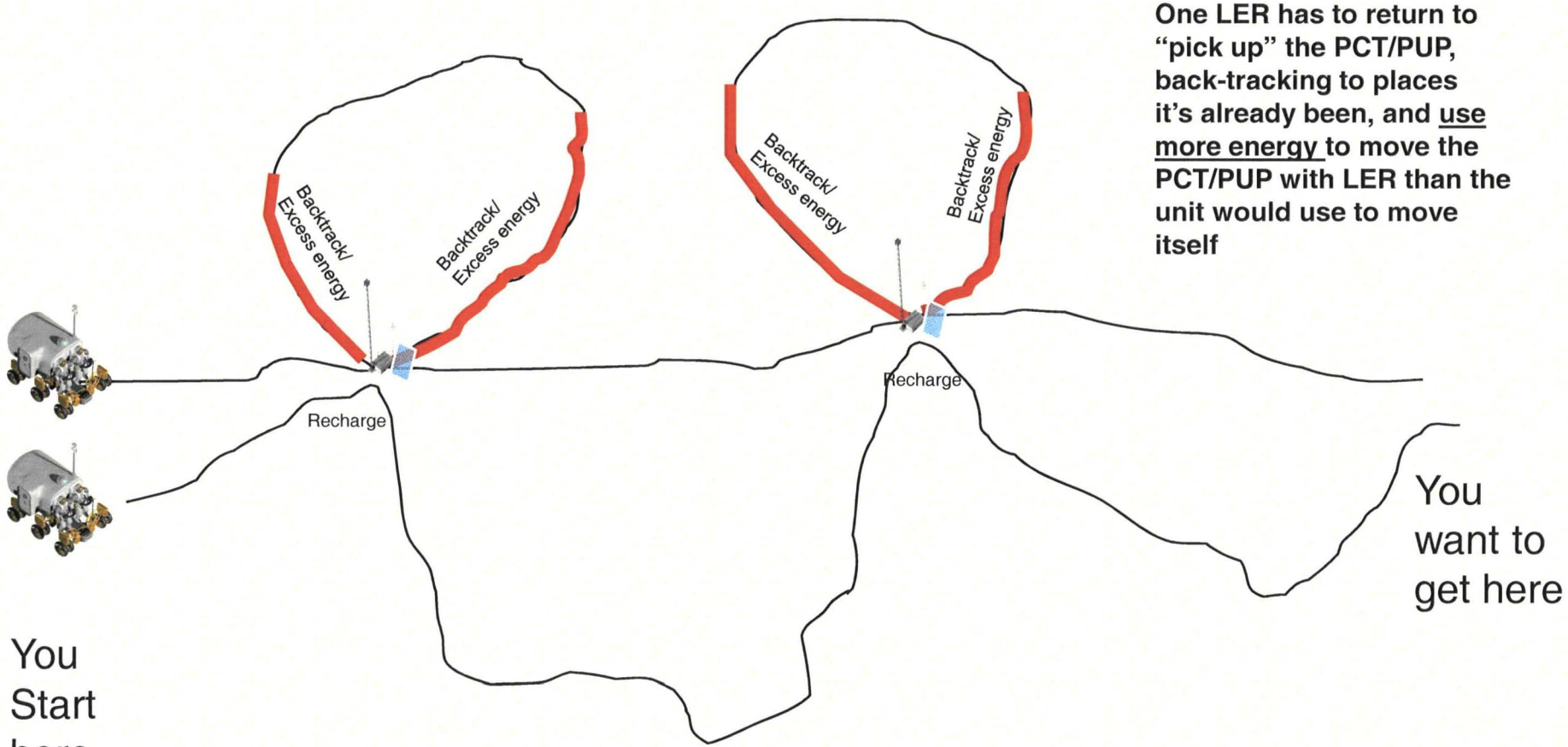
Notes:

- Positioning vessels strategically improves coverage in desired areas
- Green area is overall coverage obtained **from combination of base camp location node and the additional vessel-provided coverage**
- Notice vessel 2 is hopping packets (i.e, "meshing") through vessel 1 to get to base
- North area of the lake becomes illuminated
- South area of the lake is less illuminated, but irrelevant because no operations underway there



How a Mobile Comm/Recharge Pallet (MCRP) will save energy and exploration time

Option 1 – Portable Comm Terminal, PUP combination

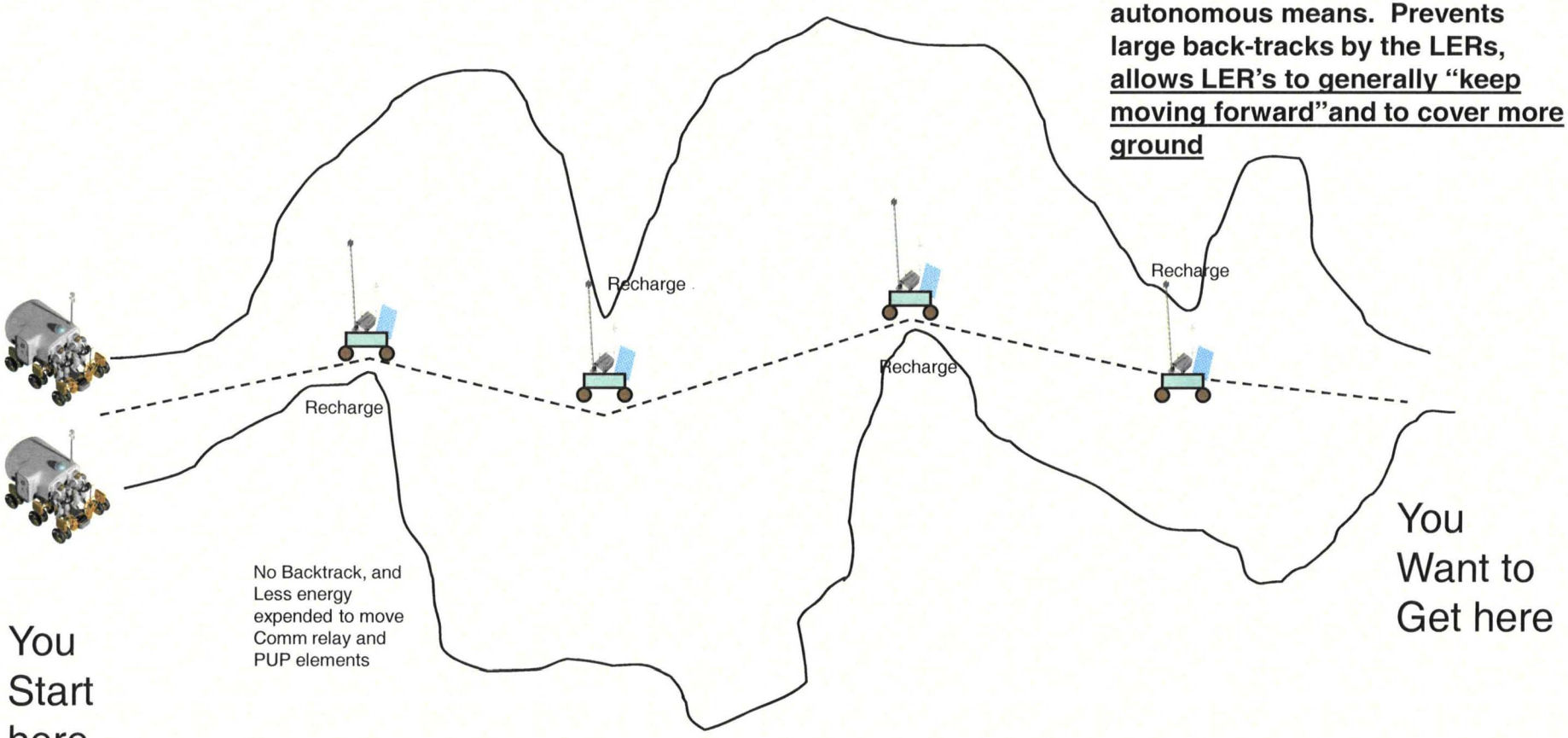


One LER has to return to "pick up" the PCT/PUP, back-tracking to places it's already been, and use more energy to move the PCT/PUP with LER than the unit would use to move itself

How a Mobile Comm/Recharge Pallet (MCRP) will save energy and exploration time

Option 2 – Mobile Comm/Recharge Pallet (MCRP) combination

MCRP is repositioned and deployed via telerobotic or autonomous means. Prevents large back-tracks by the LERs, <u>allows LER's to generally "keep moving forward"and to cover more ground</u>



You want to see as much as you can along the way