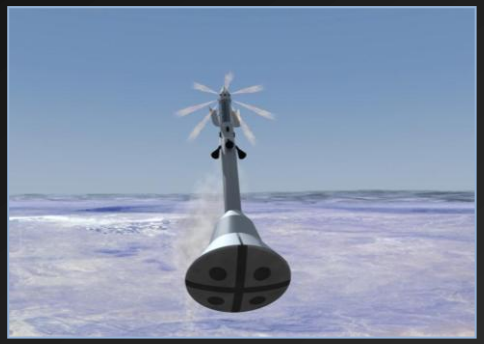
Evolving the NASA Near Earth Network for the Next Generation of Human Space Flight



May 2014

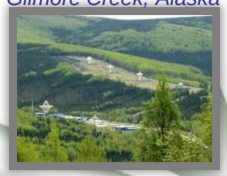
Agenda

- Project Background
- Future State Definition Study Recommendations
- Ground Architecture
- NASA and U.S. Air Force Collaboration
- Exploration Mission-1 Link Allocations
- Launch Communications Stations Driving Requirements
- Draft Users Guide Content for KUS and PDL stations
- Next Steps

NEN Global Assets

Alaska Satellite Facility
Fairbanks, Alaska

Partner Station:
NOAA CDA Station
Gilmore Creek, Alaska

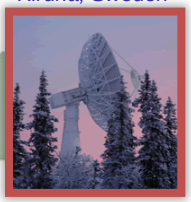


SSC/USN Alaska
Poker Flat, Alaska

SSC/USN Alaska
North Pole, Alaska

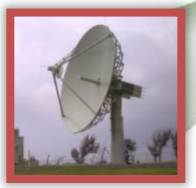
Kongsberg Satellite Services
Svalbard, Norway

Swedish Space Corp. (SSC)
Kiruna, Sweden



German Space Agency (DLR)
Weilheim, Germany

White Sands Complex
White Sands, New Mexico



SSC/USN Hawaii
South Point, Hawaii

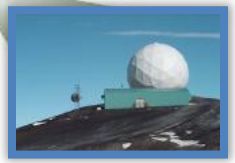
SSC/USN Australia
Dongara, Australia

NASA
Commercial
Partner

MILA and PDL
Launch Range, Florida

Wallops Ground Station
Wallops, Virginia

SSC Chile
Santiago, Chile



McMurdo Ground Station
McMurdo Base, Antarctica

Satellite Applications Center
Hartebeesthoek, Africa

Scheduling

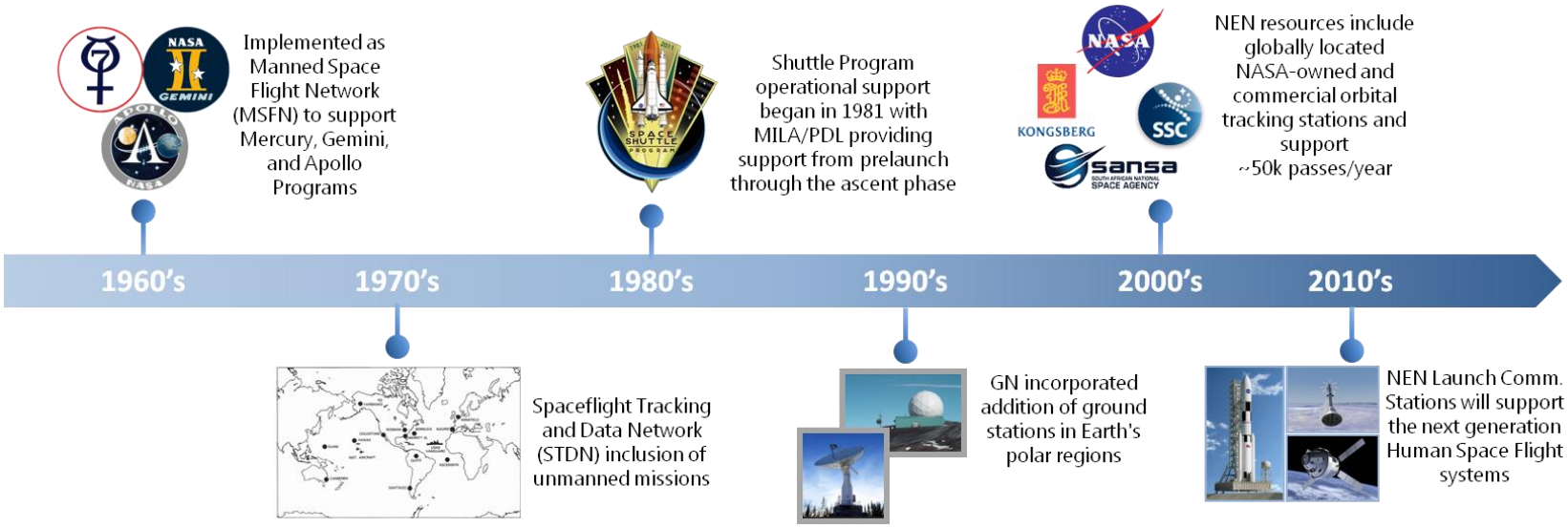
Pre-mission Planning & Analysis

Pre-mission Testing

Network Monitoring & Coordination

Near Earth Network (NEN) Mission Timeline

- The NEN Project oversees one of NASA's three space communications networks within the Space Communications and Navigation (SCaN) Program
  - Provides ground-based uplink, downlink, tracking, data processing & distribution, scheduling, remote monitor & control, testing, engineering and management services
  - Supports multiple robotic missions from low Earth orbit to lunar orbit using a mix of NASA-owned stations and cooperative agreements with commercial and international space communications providers
- The NEN traces its origin to the NASA Human Space Flight (HSF) program
  - First implemented as the Manned Space Flight Network to support the Mercury Program
  - Provided unique HSF launch & landing uplink comm. until the end of the Shuttle Program
- The NEN is now leading a major Systems Engineering initiative, the Launch Communication Stations (LCS) development project, to rebuild and expand its launch communication stations for the next generation of HSF



Range Future State Definition (FSD) Study

- A Presidentially directed Range Future State Definition (FSD) Study[1] of Florida launch range infrastructure modernization concluded in September 2012
  - Led jointly by Kennedy Space Center (KSC) Ground Systems Development and Operations (GSDO) Program and the United States Air Force (USAF) Eastern Range
  - *"An East Coast launch support capability with NASA infrastructure and systems complementing the Air Force Eastern Range, using integrated, common processes to provide flexible, affordable, and responsive support to the multi-user community."*
- The FSD Study team issued 25 Near-term (2012-2015) and 19 Long-term (2015-2025) recommendations, two of which are directly addressed by the LCS development project

Increased Telemetry Downlink Data Rates

Recommendation #1:
Joint Air Force and NASA FY13 project to provide the minimum 20 Mbps TLM downlink data rate identified in study and support architectures

Uplink Capability to Vehicle and/or Crew

Recommendation #2:
Develop the ground-based requirements and implement the telemetry (S-Band) systems that will provide digital uplink capability. Document the requirements, involved agencies, location options, and costs/resources information

- NEN, in conjunction with GSDO and USAF, developed a multi-user ground architecture concept consistent with the FSD Study recommendations and driven by the Exploration Mission-1 requirements and schedule constraints

[1] ***FSD-008, Sep. 2012, a presidentially directed study of launch infrastructure modernization.***

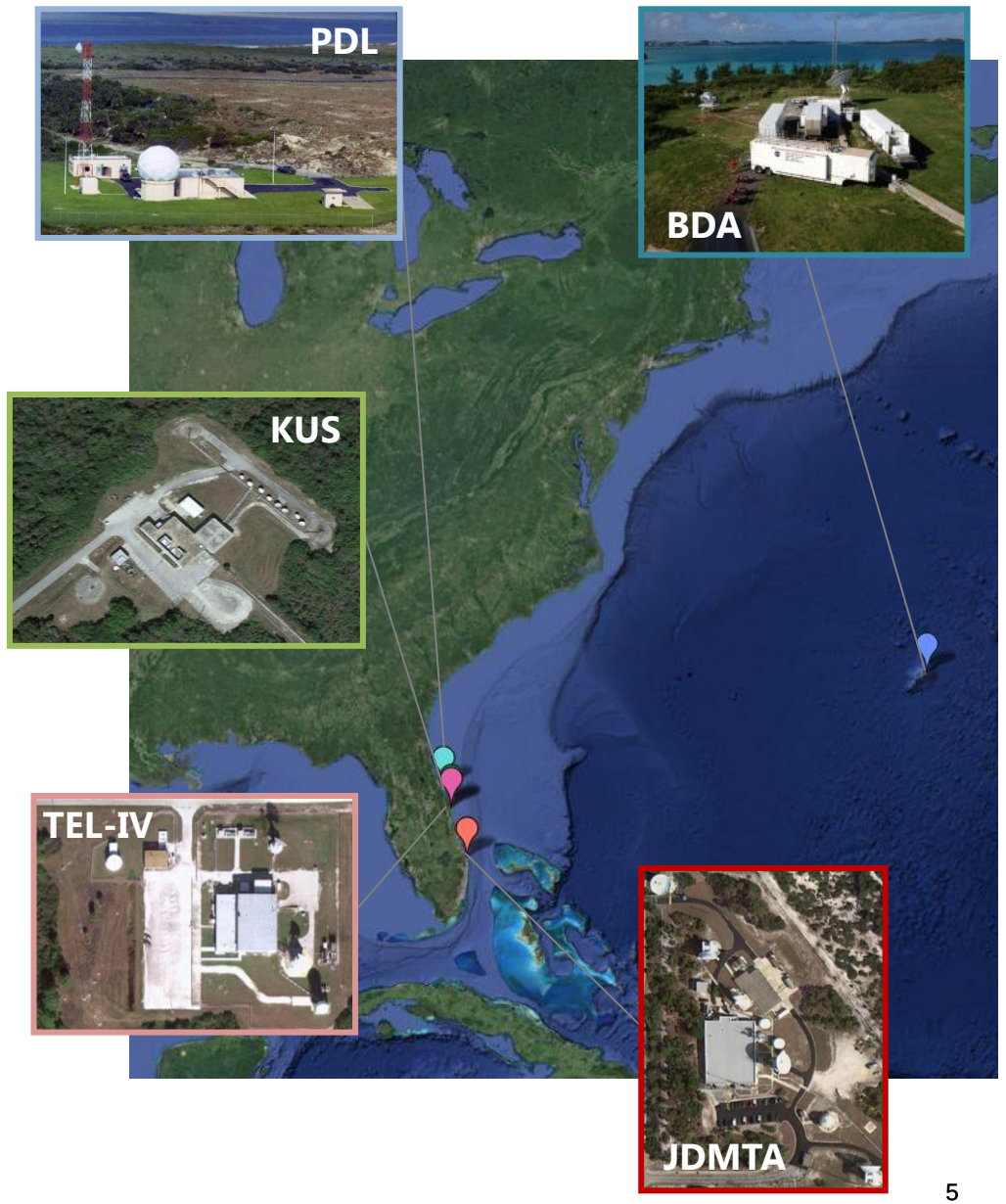
Ground Architecture

Multi-user ground architecture using NASA and USAF stations and cooperative agreements consistent with FSD recommendations to fully satisfy Exploration Mission-1 (EM-1) requirements

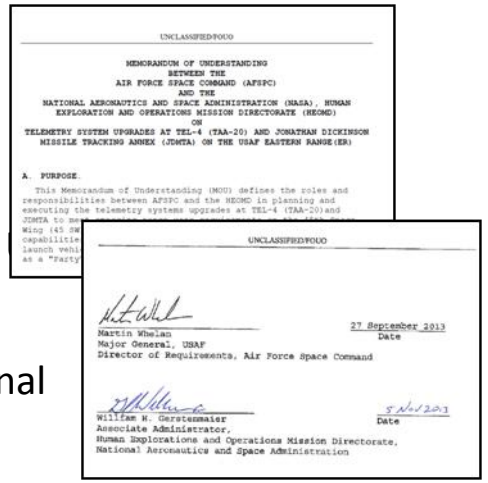
- ***Two NEN stations, each provide S-band uplink, 20 Mbps Downlink, modern signal & data format processing, and near real time data recording & distribution***
  - *Launch-area: Kennedy Uplink Station (KUS)*
  - *Wing site: Ponce De Leon (PDL) station*
- ***Two USAF stations, each provide 20 Mbps downlink modern signal & data format processing, and data recording***
  - *Launch area: TEL-IV (TAA-20)*
  - *Wing site: Jonathan Dickinson Missile Test Annex (JDMTA) station*

The LCS project will also oversee the development of a downrange site in cooperation with the Wallops Range

- ***One Wallops Range station, 20 Mbps Downlink, modern signal & data format processing, and near real time data recording & distribution***
  - *Downrange: Bermuda Ground Station (BDA)*



NASA-USAF Collaboration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MEMORANDUM OF UNDERSTANDING
BETWEEN THE
AIR FORCE SPACE COMMAND (AFSPC)
AND THE
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA), HUMAN EXPLORATION AND OPERATIONS MISSION DIRECTORATE (HEOMD)
ON
TELEMETRY SYSTEM UPGRADES AT TEL-4 (TAA-20) AND JONATHAN DICKINSON MISSILE TRACKING ANNEX (JDMTA) ON THE USAF EASTERN RANGE(ER)

A. PURPOSE.

This Memorandum of Understanding (MOU) defines the roles and responsibilities between AFSPC and the HEOMD in planning and executing the telemetry systems upgrades at TEL-4 (TAA-20) and JDMTA to

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Martin Whelan
Major General, USAF
Director of Requirements, Air Force Space Command

27 September 2013
Date

William H. Gerstenmaier
Associate Administrator,
Human Explorations and Operations Mission Directorate,
National Aeronautics and Space Administration

Date

- NASA-USAF MOU outlining cooperation obtained final approval from Major General Martin Whelan and Associate Administrator William Gerstenmaier on November 6, 2013
  - Equipment transfers from USAF to NASA and an associated set of legacy signal and data format requirements
- The LCS project is responsible for executing pre-SRR through Operational Readiness Review project milestones, and will own and control:
  1. All of the equipment at the NASA stations
  2. One antenna system (TAA-20) and the high rate signal and data processing and recording equipment deployed at the USAF TEL-IV station
  3. The high rate signal and data processing and recording equipment deployed at USAF JDMTA station
- Post ORR, LCS will transfer ownership to USAF of all equipment installed at the USAF stations
- NEN will operate, maintain and sustain the NASA stations and USAF personnel will operate, maintain and sustain the LCS installed equipment at the USAF stations

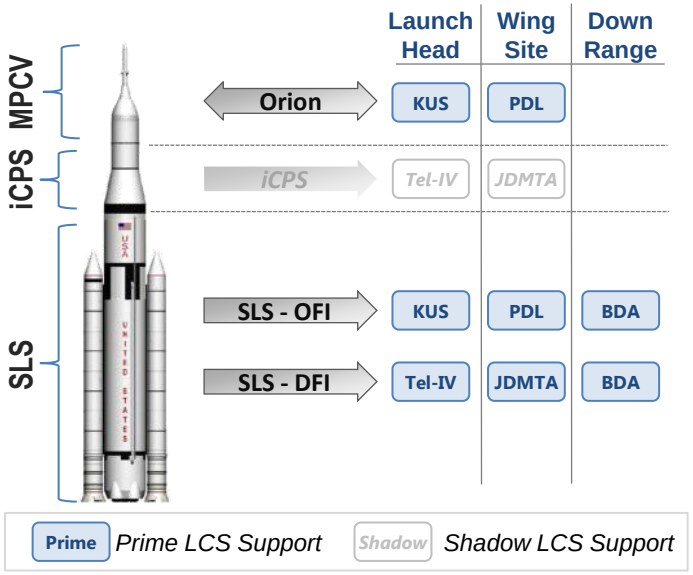
USAF provided antenna systems for KUS and PDL in storage at KSC

EM-1 Link Allocation

- **The LCS equipment will support the following RF links for SLS and MPCV from KUS and PDL**
  - SLS: OFI downlink
  - MPCV: Launch Abort System (LAS) and Service Module (SM) downlink and uplink
- **The LCS equipment will support the following RF links for SLS from AF Stations TEL-IV and JDMTA**
  - SLS: DFI downlink
  - *SLS/iCPS: Record only shadow operations with legacy USAF equipment*
- **The LCS equipment will provide support for the following RF links for SLS from the Bermuda Station**
  - SLS: OFI and DFI downlink

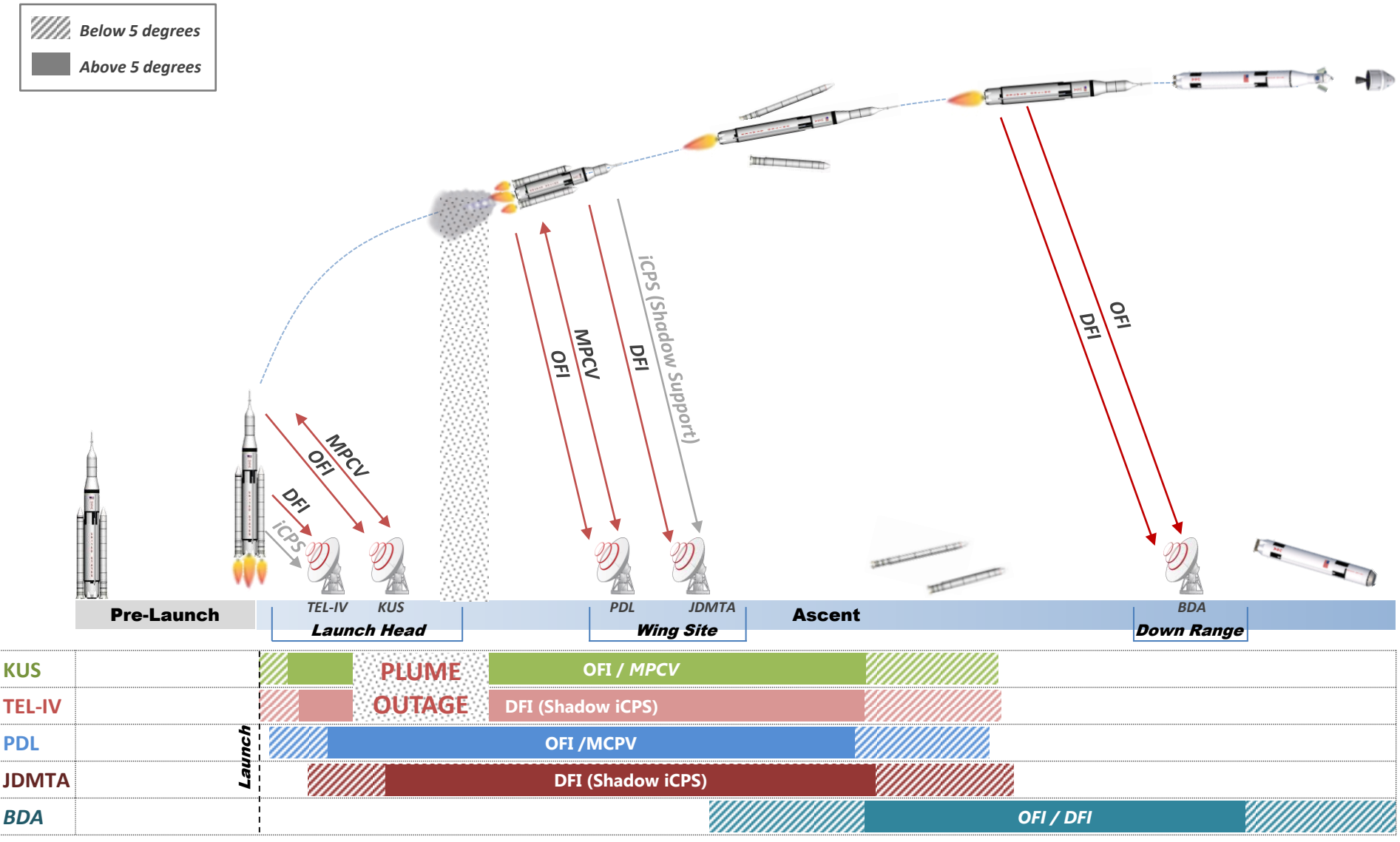
SLS - OFI	***Link Characteristics*** *S-band RF downlink with an encoded data rate of 20 Mbps. The link will be modulated using SQPSK, LDPC 7/8 encoded and transmitted using RHCP; Data format is CCSDS*
SLS - DFI	***Link Characteristics*** *S-band RF downlink with an encoded data rate of 20 Mbps. The link will be modulated using SQPSK, LDPC 7/8 encoded and transmitted using RHCP; Data format is CCSDS*
MPCV-Rx	***Link Characteristics*** *S-band RF downlink with an encoded data rate of 384 ksps. The link will be modulated using SQPN, LDPC 1/2 encoded and transmitted using RHCP; Data format is CCSDS*
MPCV-Tx	***Link Characteristics*** *S-band RF uplink with an encoded data rate of 144 ksps. The link will be modulated using SS-UQPSK, LDPC 1/2 encoded and transmitted using RHCP; Data format is CCSDS*

EM-1 Launch & Ascent Comm. Links*



**** This diagram shows the LCS ground sites and their allocated user links. It does not include other SCaN or Air Force assets nor their user link allocations.***

EM-1 Link Allocation (continued)



Note: This diagram shows the LCS ground sites and their allocated user links. It does not include other SCaN or Air Force assets nor their user link allocations.

Requirements Process: EM-1 Driving Requirements (1/2)

Driving Requirement	Design Consequence	Rationale
Avoidance of SRB Plume Induced Comm. Outage	Launch Area and Wing Site Stations required	Legacy sites and trajectory analyses
99.1% Reliability/Availability	Dual string redundant signal processing electronics per RF link	Within NEN experience
Uplink Link Budget Margin Exceeds 3 dB	Equivalent Isotropically Radiated Power (EIRP) characteristics (KUS and PDL only)	Link budget analysis of LCS reference design
S-band Uplink	Antenna feed modifications and associated uplink equipment (KUS and PDL only)	Within NEN experience
Downlink Link Budget Margin Exceeds 3 dB	Antenna Gain-to-Noise-Temperature Ratio (G/T) characteristics of each station	Link budget analysis of LCS reference design
Multi-Carrier S-band Downlink	Filtering, down conversion and equipment configuration	Within NEN experience
20 Mbps Downlink (encoded)	Modern high data rate signal processing equipment	Within NEN experience
C-band Downlink Upgrade Capable	KUS and PDL station antenna feed modification for S-band Uplink shall not preclude future C-band telemetry upgrade kit	Commercially available field upgrade kit
SQPN and SS-UQPSK Modulations	Modern signal modulation/de-modulation equipment, may require additional software (SW) licenses (KUS and PDL only)	New to NEN but readily available COTS

Requirements Process: EM-1 Driving Requirements (2/2)

Driving Requirement	Design Consequence	Rationale
LDPC ½ and LDPC 7/8 Encoding	Modern signal encoding/decoding equipment, may require additional SW licenses	New to NEN but readily available COTS
CCSDS Data Formats	Modern data processing equipment, may require additional SW licenses	Within NEN experience
Best Frame Select	Modern data processing equipment	Within NEN experience
Near Real Time Data Distribution using SLE	Modern processing equipment integrates SLE distribution functionality (additional SW licenses) and stand alone Space Link Extension (SLE) hardware readily available [1] Implementation may drive potential changes to Monitor & Control SW	New to NEN, but SLE within NASA experience; commercially available Per SNIP requirements, (CCSDS Orange Book compliant) common SLE I/F with multiple data end users New CSO Network Architecture
Low Cost Operations	Remote operations of KUS and PDL stations from NEN Wallops Operations Center	Within NEN experience

[1] Ongoing SLE trade study conducted in coordination with SCaN Network Integration Project (SNIP) Team.

KUS/PDL Capabilities Overview (Draft NEN Users Guide Content)

- KUS and PDL will both feature a 6.1m antenna capable of simultaneously transmitting and receiving at S-band, with a planned evolution to C-band telemetry by EM-3 (post 2021)
- KUS and PDL will be remotely monitored and controlled from the NEN Wallops Ops. Center
- KUS and PDL will be scheduled by the NEN schedulers at WSC using WOTIS
- Tracking Services (Antenna Autotracking Angle Data): [1]
  - KUS and PDL will both be capable of recording the angle of the ground antenna as it autotracks the user
  - Angle data will be provided to the FDF as Universal Tracking Data Format (UTDF) files or CCSDS Tracking Data Messages (TDM) (TBR)
- Data Interfaces (IP - CCSDS SLE):
  - KUS and PDL will both be capable of sending and receiving baseband data in IP formats
  - Real-time data and commands will be handled per CCSDS Orange Book SLE
  - Post-pass playbacks will be made available for retrieval using the SLE offline mode
  - KUS will have a fiber connection with the CD&SC to support uplink and telemetry
  - PDL will have a CSO connection with the CD&SC to support uplink and telemetry
  - Best Frame Select will occur in the CD&SC and provide AOS Transfer Frames via SLE to the mission data end users

[1] ***Doppler and Ranging capabilities could be made available if required***

KUS/PDL Downlink Capabilities
(Draft NEN Users Guide Content)

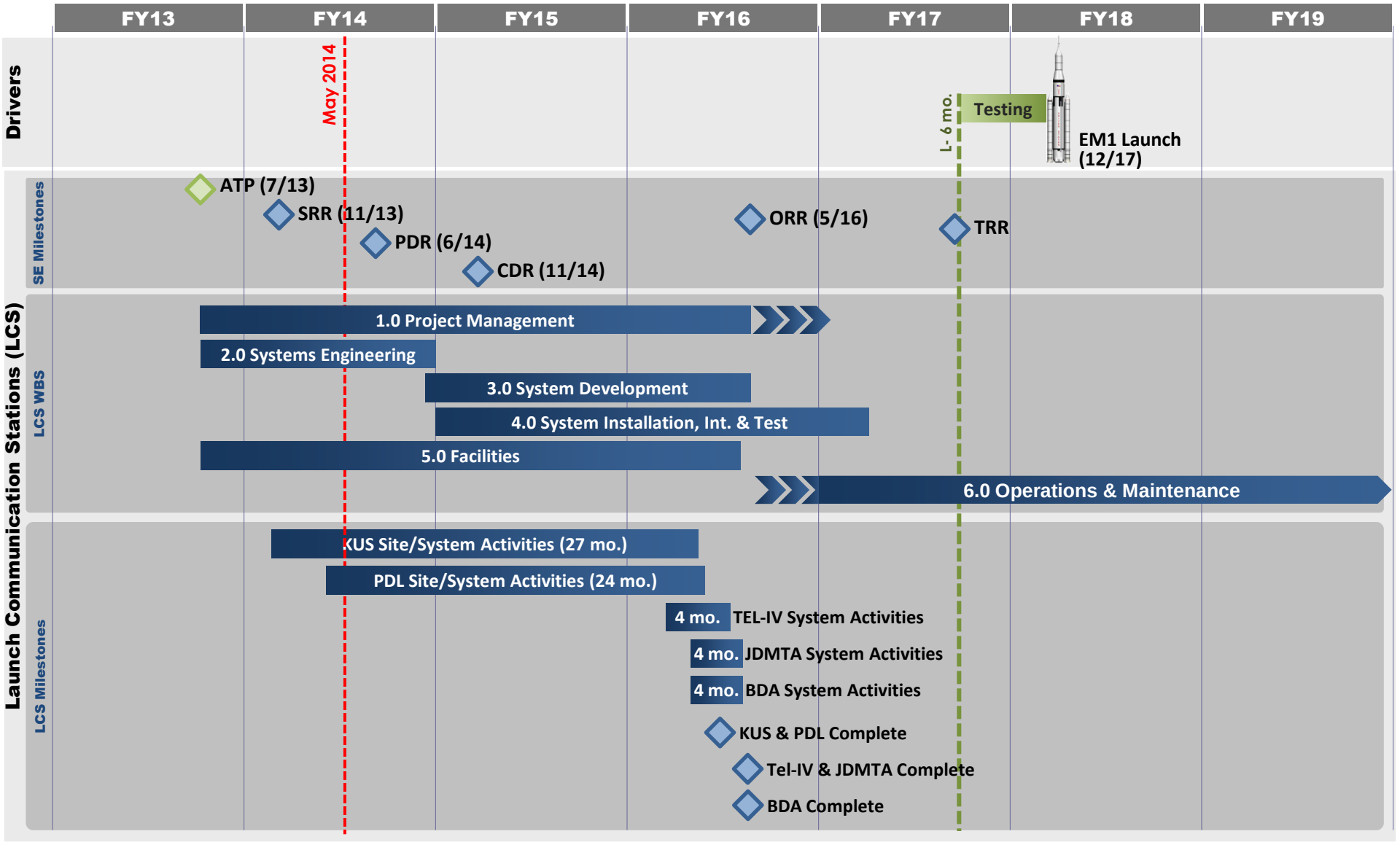
Characteristic	Value
Frequency	2200-2400 MHz
G/T	14.1 dB/K
System Noise Temperature	TBD
Polarization [1]	RHC or LHC Diversity combination of RHCP/LHCP (pre/post detection)
Antenna Gain	TBD
Antenna Beamwidth (3-dB)	TBD
Carrier Demodulation	PCM/PM, PCM/FM BPSK, QPSK, OQPSK/SQPSK [SLS], AQPSK, GMSK, SQPN [MPCV]
PM Modulation Index	0 to 2.5 radians
FM Deviation	0 MHz to +/- 500 kHz
Carrier Information Rate	100 bps to 40 Mbps (Modulation and coding dependent)
Carrier Line Coding	NRZ: L,M,S / BiΦ: L, M, S / DBP: M, S / DM: M, S / R-NRZ /V35
Subcarrier Frequency	40 Hz to 128 kHz (Low Bandwidth Telemetry Mode) 5 kHz to 2 MHz (High Bandwidth Telemetry Mode)
Subcarrier Demodulation	BPSK (with PCM/PM or PCM/FM as carrier modulation)
Subcarrier Information Rate	7 bps to 25 kbps (Low Bandwidth Telemetry Mode) 100 bps to 600 kbps (High Bandwidth Telemetry Mode) *Modulation and coding dependent
Subcarrier Line Coding	NRZ: L,M,S / BiΦ: L, M, S (Low or High Bandwidth Telemetry Mode) DBP: M, S / DM: M, S / R-NRZ (High Bandwidth Telemetry Mode)
Decoding	Viterbi ½, Reed-Solomon (255, 223) i = 1 to 5, Concatenated (Reed-Solomon/Convolutional) LDPC ½ [MPCV], LDPC 7/8, (8160, 7136) [SLS], Turbo Code ½

[1] Post Detection Diversity Combining is available for the following modulations schemes: Video Mode (PM), PCM Mode (PCM/PM, PCM/BPSK, PCM/QPSK, PCM/OQPSK). Pre Detection Diversity Combining is available for the following modulations schemes: Video Mode (PM, FM, Coherent/Non-Coherent FM), PCM Mode (PCM/PM, PCM/BPSK, PCM/QPSK, PCM/OQPSK)

KUS/PDL Uplink Capabilities (Draft NEN Users Guide Content)

Characteristic	Value
Frequency	2025-2120 MHz
EIRP	56 dBWI
Polarization	RHC or LHC
Antenna Beamwidth	1.7° (TBR)
Antenna Gain	39 dBi (TBR)
HPA	200 W
Carrier Modulation	PM, FM BPSK, QPSK, OQPSK/SQPSK, AQPSK, GMSK, SS-UQPSK [MPCV]
Modulation Index	PM: 1 – 2.5 radians FM: 0 to +/- 5 MHz
Carrier Data Rate	7 bps to 10 kbps (Low Bandwidth Command Mode) 100 bps to 600 kbps (High Bandwidth Subcarrier Command Mode) 100 bps to 1 Mbps (High Bandwidth PCM Command Mode)
Carrier Data Format	NRZ: L,M,S / BiΦ: L, M, S / R-NRZ
Subcarrier Frequency	40 Hz to 100 kHz (Low Bandwidth Command Mode) 5 kHz to 2 MHz (High Bandwidth Subcarrier Command Mode)
Subcarrier Modulation	BPSK (with PCM/PM or PCM/FM as carrier modulation)
Subcarrier Data Rate	7 bps to 10 kbps (Low Rate Command Mode) 100 bps to 600 kbps (High Rate Command Mode)
Subcarrier Data Format	NRZ: L,M,S / BiΦ: L, M, S / R-NRZ
Coding	Convolutional ½, LDPC ½ [MPCV]

LCS High Level Development Schedule



Next Steps

- Refurbishment of the two 6.1m antenna subsystems is underway
- Kennedy Uplink Station civil infrastructure development is progressing on schedule
- Draft agreements with mission partners are in place
- Initiating transmit license spectrum request for KUS and PDL with NTIA
- Continuing coordination with SCaN Network Integration Project (SNIP) on Space Link Extension implementation options
- LCS Preliminary Design Review is scheduled for June 11-12 at Wallops Flight Facility

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