Space Network (SN) Low-Density Parity-Check (LDPC) Code Implementation (SLI)

Human Spaceflight Network Support Group

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SLI Background and Objectives

- **Task Order-84 (TO-84) began in April 2011 under the GSFC Space Communications and Network Services (SCNS) contract**
- **Support Exploration Flight Test-1 (EFT-1) mission requirements**
- **Avoid impacting high priority SN Projects:**
  - Tracking and Data Relay Satellite – K (TDRS – K) project
  - User Services Subsystem (USS) – Component Replacement (USS-CR) project
- **Design an architecture capable of easy installation and removal**
  - Minimize legacy equipment configuration modifications
  - No impact to operations
  - No legacy software modifications
  - Small footprint

SLI EFT-1 Support

- **SLI support**
  - **Add Rate ½ LDPC capability to WSC**
  - 1 East and 1 West TDRS (not necessarily TDRS East and TDRS West satellites)
    - 1 Single Access (SA) chain (prime and backup)/SGLT
    - The 2 SGLTs supporting EFT-1 have not been selected
  - No Zone of Exclusion (ZOE) support from GRGT
    - 2nd orbit will not have a ZOE because of apogee maneuver and high altitude
  - S-Band services only
    - Forward (48 ksps and 144 ksps)
    - Return (72 ksps, 384 ksps, and 1 Msps)
    - Non-coherent services only
    - Provide forward service Doppler compensation
    - No Tracking Data Messages (TDMs) or User Performance Data (UPDs) on return service
    - Status parameters will be logged during the mission and made available to EFT-1 post mission
- **EFT-1 mission support**
  - Premission risk mitigation and compatibility testing
  - EFT-1 mission (approximately 4 1/2 hours)

SLI Supported Data Rates

Mode	Information Rate (Note)	Symbol Rate (Note)	Modulation	Data Group	Data Format	Antenna Polar.	Phase
S-Band VLDR Forward	23.2727 kbps	48 ksps	SS-UQPSK	N/A	NRZ-L	RHCP (PAA)	LEO, Re-entry, & Recovery
S-Band LDR Forward	69.8182 kbps	144 ksps					L&A, LEO, Re-entry, & Recovery
S-Band VLDR Return	34.9091 kbps	72 ksps	SQPN	Data Group 1 (DG1) Mode 2 Non-coherent			LEO Re-entry, & Recovery
S-Band LDR Return	186.1818 kbps	384 ksps					L&A, LEO Re-entry, & Recovery
S-Band MDR Return	0.4849 Mbps	1 Msps	SQPSK	Data Group 2 (DG2) Mode 2 Non-coherent			LEO

Note: The EFT-1 information rate is the rate prior to any coding. The EFT-1 symbol rate is the rate with all encoding applied referenced at the input of the modulator including 64-bit Attached Sync Marker (ASM).

Key EFT-1 Mission Characteristics Affecting SN support

- EFT-1 uses Rate ½ LDPC coding for communication
- **Crew module uses 4 Phased Array Antennas (PAAs) for communication**
  - Separated by 90 degrees
  - Covered by Launch Abort System (LAS) until approximately L+6 minutes
  - 1 PAA radiates at a time ("Break before Make")
- **EFT-1 slew rate**
  - ½ degree per second during majority of mission
  - Communication dropouts
    - Expected every 3 minutes (PAA transitions) during majority of mission
    - Reentry, caused by violent vehicle oscillations
- **Apogee raising maneuver during 2nd orbit increases EFT-1 apogee to approximately 5000**
  - Eliminates ZOE during 2nd orbit

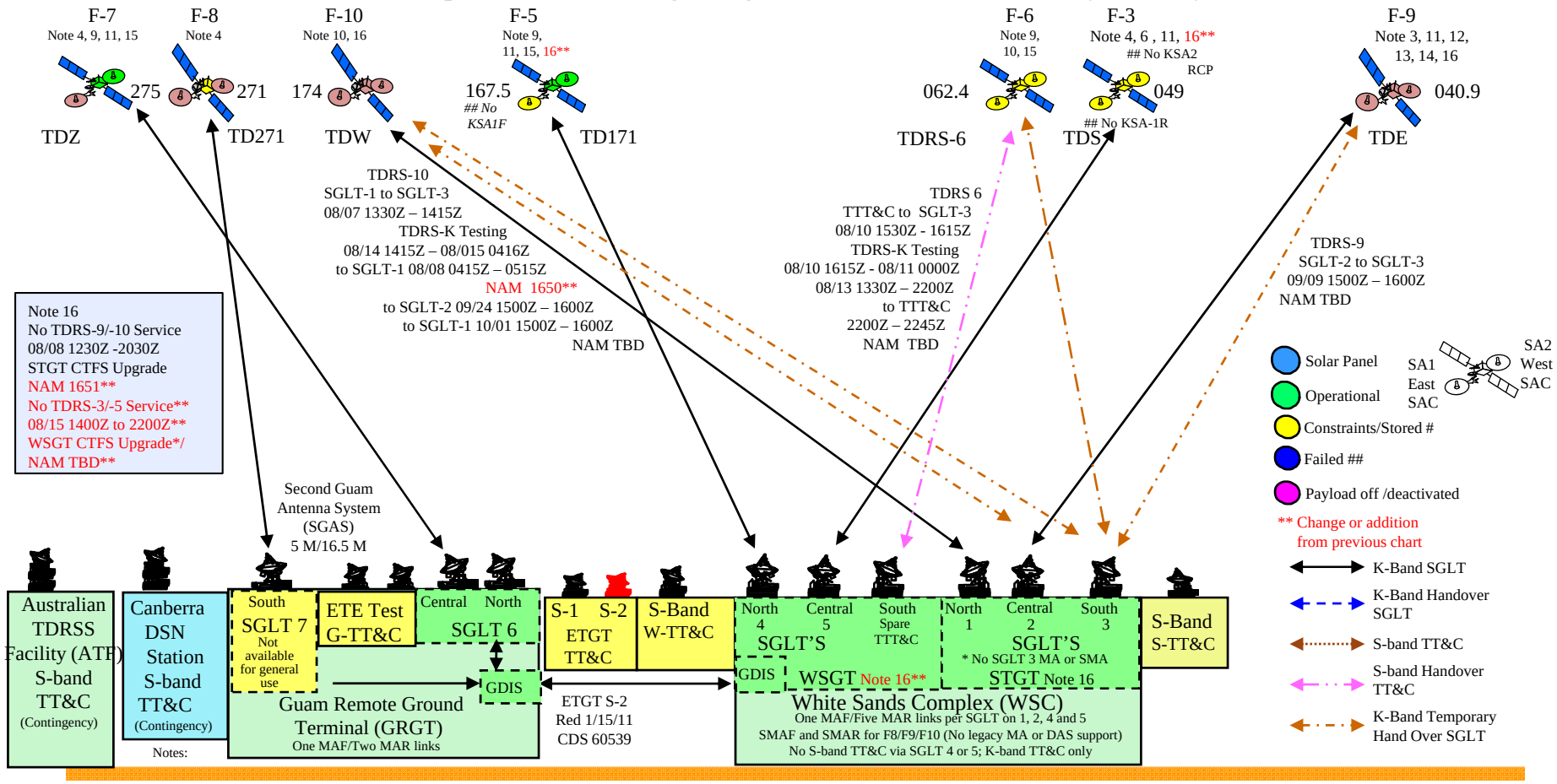
SN LDPC Capability

- **Rate ½ LDPC**
  - Block encoding algorithm
    - Requires more powerful processing capability
    - Intended for National Aeronautics and Space Administration (NASA) Constellation project support
  - **Not supported by legacy SN equipment**
- **Ongoing SN Projects adding LDPC capability**
  - SN Ground Segment Sustainment Project (SGSS)
    - Redesign the architecture at WSC and the Guam Remote Ground Terminal (GRGT)
    - Currently in the requirements phase, implementation scheduled for 2015 and beyond
  - User Services Subsystem (USS)-Component Replacement (USS-CR) project
    - Procuring Narrow Band (NB) modems with LDPC capability and other equipment for the White Sands Ground Terminal (WSGT) Space Ground Link Terminals (SGLTs) 4 and 5
    - Implementation schedule does not support the EFT-1 test schedule
- **SLI project is leveraging knowledge and equipment from USS-CR program**
  - Borrow spare USS-CR NB modems (referenced as SLI modem for this presentation) to support EFT-1
  - Utilize USS-CR test program results to reduce I&T for SLI project

Current SN Configuration

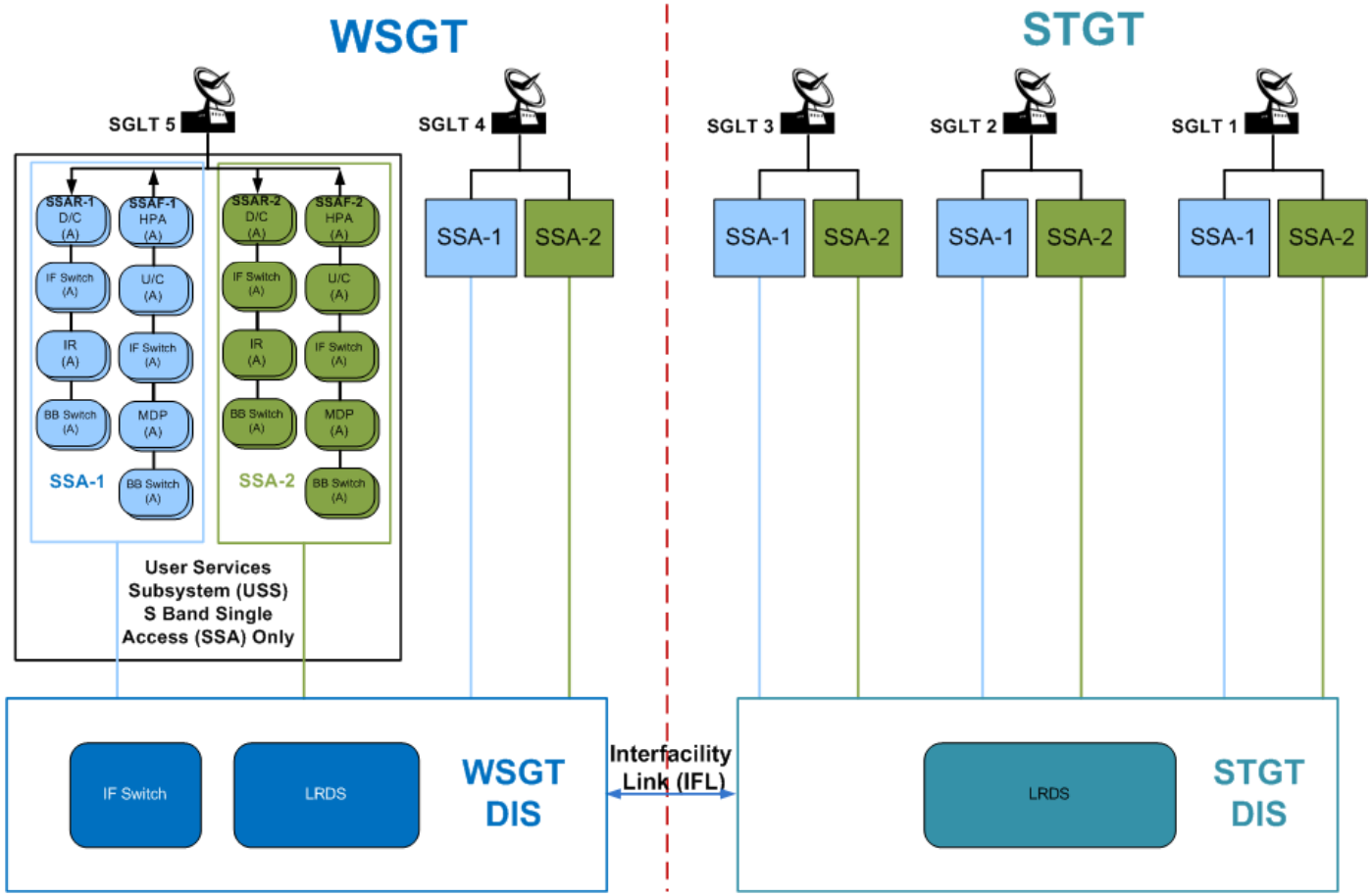
TDRS Space Network Configuration/July – Oct. 2012

(07/19 Version per WSC SN Long Range Calendar Dated Thursday, 19July 2012)



WSC SSA Configuration

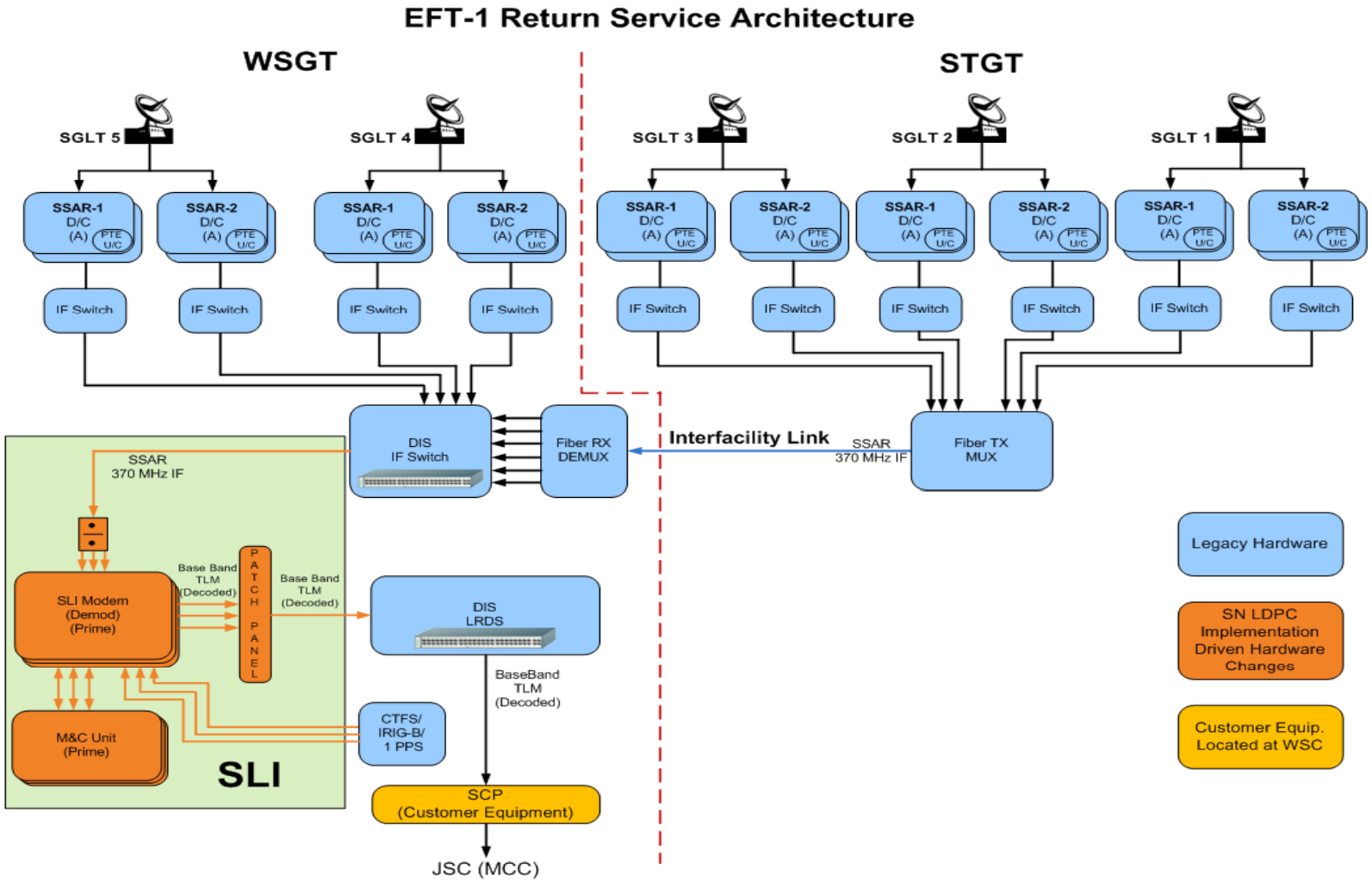
Legacy WSC SSA Signal Architecture
(EFT-1 Related)



SLI "IF Switch" Architecture Details

- **Supports any WSGT/STGT SLGT combination**
- **SLI equipment is only located at WSGT**
- **Minimal equipment required**
  - 1 prime/2 backup SLI modems and simplified M&C units
  - Patch panel
  - Splitter
  - Cables
- **Utilizes automated legacy M&C infrastructure where possible**
- **SLI modem is only connected to DIS IF Switch and LRDS (via patch panel) at WSGT**
- **M&C unit and SLI modem are isolated from legacy USS equipment**
- **Utilizes IFL to route signals to/from STGT if needed**

SLI Architecture (Return Service)

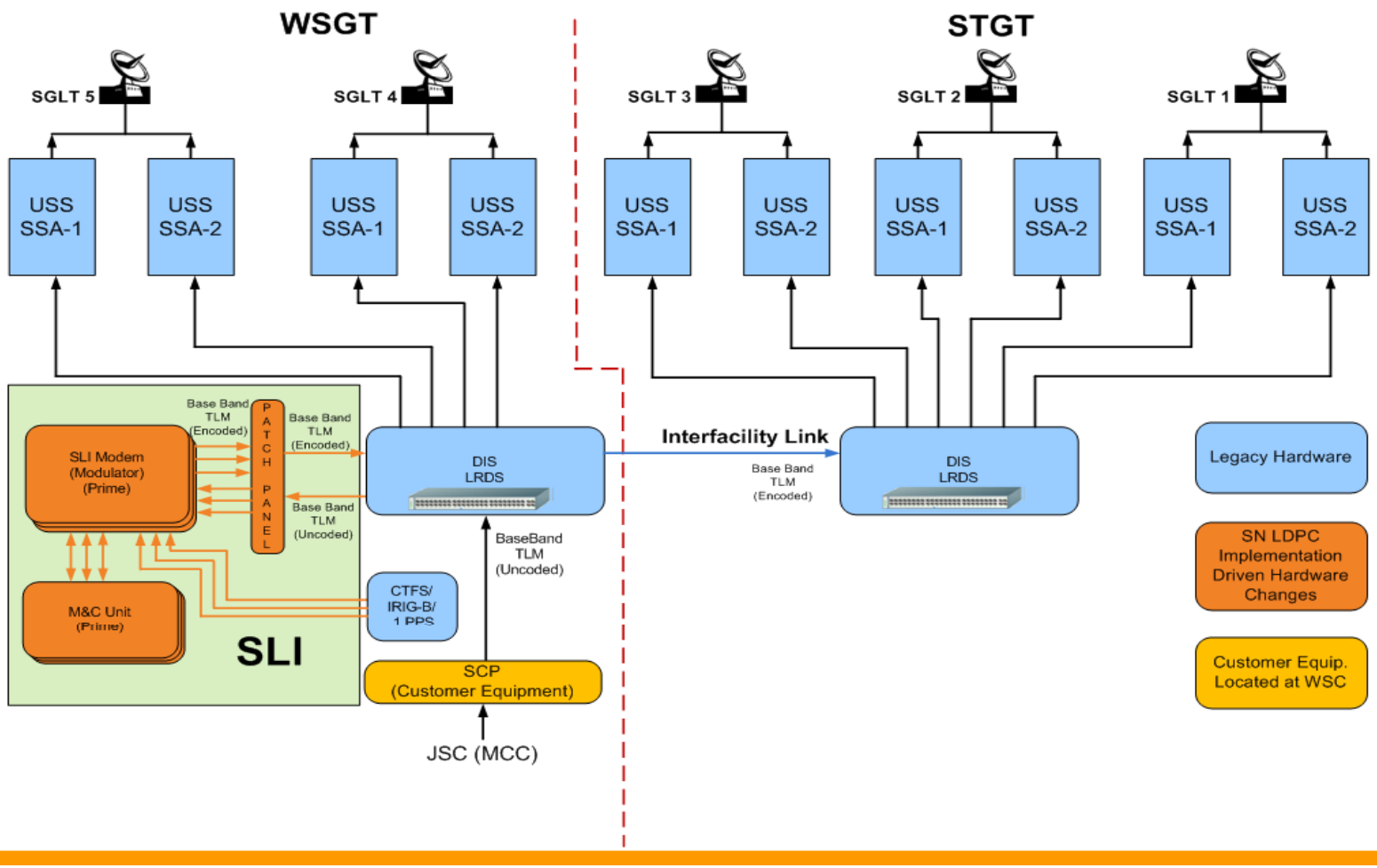


SLI Architecture
Return Service Details

- **Return Service Signal Processing:**
  - Downconverter receives the RF signal from the SA antenna and down converts the signal to a 370 MHz IF signal
  - IF signal is routed to the DIS IF
    - WSGT – USS IF switch routes IF signal directly to WSGT DIS IF switch
    - STGT – USS IF switch routes the switch to the WSGT DIS IF switch via the IFL
  - The DIS IF switch transmits the IF signal to the SLI modems (signal is split and sent to prime and backup modems)
  - SLI modems
    - Demodulation
    - Frame sync
    - Remove ASM
    - Derandomization
    - LDPC decoding
    - Reattach ASM
  - SLI modems transmit decoded BB signal to DIS LRDS via patch panel (selects SLI modem input source)
  - LRDS transmits decoded data and clock to the SCP
  - SCP transmits decoded data to the Mission Control Center (MCC) at Johnson Space Center (JSC)

SLI Architecture (Forward Service)

EFT-1 Forward Service Architecture



SLI Architecture
Forward Service Details

- **Forward Service Signal Processing:**
  - LRDS receives uncoded AOS frames from SCP
  - LRDS routes uncoded AOS frames (BB signal) to SLI modems via patch panel
  - SLI modem
    - Frame sync
    - LDPC encoding
    - Randomization
    - Reattach ASM
    - SLI modem does not modulate the signal (SLI modem firmware modification required)
  - Encoded BB signal is routed back to LRDS via patch panel
  - LRDS routes encoded bit stream to legacy MDP via BB Switch (WSGT)
    - STGT – forward data is routed to STGT DIS LRDS via IFL then to BB switch and MDP
  - MDP routes the signal to the up converter
    - Adds forward Doppler compensation
    - SS-UQPSK modulates the data to a 370 MHz IF signal
  - Up converter converts the signal to an RF signal and routes the signal to High Power Amplifier (HPA)
  - HPA amplifies the signal and routes the signal to the SA antenna and TDRS

SLI Architecture
Pros and Cons

- **Advantages:**
  - Increased flexibility
    - Supports selection of any SGLT pair
      - Changes in TDRS locations can be accommodated
      - SGLTs selected for mission support can be selected after ETE test
      - Minimal equipment reconfiguration required to support different SGLTs
    - Minimal equipment reconfiguration required after pre-mission testing is completed
  - SLI equipment only located at WSGT
    - Utilizes the SCP at WSGT
      - STGT SCP can continue ISS support
    - Only requires 3 SLI modems and M&C units
  - Reduced Testing
    - SLI setup will remain intact after initial integration and test
    - Less complex
    - One location
  - Decreased costs
    - Fewer support personnel required
      - Reduced training
    - Less equipment required

SLI Architecture
Pros and Cons (cont.)

- **Advantages (cont.):**
  - Does not interfere with the USS-CR project integration
  - Legacy MDP provides forward service Doppler compensation
  - Utilizes SHOs and Ground Control Message Requests (GCMRs) for legacy equipment commands
  - No impact to legacy equipment
- **Disadvantages:**
  - Partial manual equipment configuration required
  - Real-time TDMs and UPDs are not available
  - Requires DIS IF switch ports (available and already assigned)
  - Does not support overlapping SHOs
    - Verified with EFT-1 not required for mission support
    - Not supported by current SCP configuration

SLI Modem Modifications

- **Modify existing forward service to output Rate ½ LDPC forward command stream as a BB signal**
- **No changes required to support EFT-1 return services**
- **Create new SLI specific status display for EFT-1**
- **Create new SLI specific status logs for EFT-1**
  - Periodic status logs
  - Event logs – forward and return lock

Project Milestones

MILESTONE	Date
System Requirements Review (SRR)	5/25/2011
Risk Mitigation Test-1 (RMT-1)	2/13/2012-2/27/2012
Design Briefing	7/26/2012
SLI Modem Firmware Modifications Complete	10/2/2012
WSC System Integration and Testing Complete	12/2012
Risk Mitigation Test-2 (RMT-2)	3/2013
Live-Sky Test	3/2013
EFT-1 End-To-End (ETE) Test @ KSC O&C	7/2013
Flight Readiness Review (FRR)	3/2014
EFT-1	4/2014

EFT-1 Pre-Mission Testing

	RMT-1	RMT-2	Live-Sky	End-to-End
Time Frame	February 2012	March/April 2013	March/April 2013	July 2013
Location	CTIL at Denver	CTIL at Denver JSC	CTIL at Denver, JSC, WSC	JSC, KSC, WSC
Operations Involved	None	WSC	WSC, JSC	JSC, KSC, WSC
Engineering Participants	NASA JSC Contractors LM, CSC, ITT Exelis	NASA JSC Contractors LM, CSC, ITT Exelis	NASA JSC Contractors LM, CSC, ITT Exelis	NASA JSC KSC Contractors LM, CSC, ITT Exelis