Tracking and Data Relay Satellite System Demand Access System Augmentation

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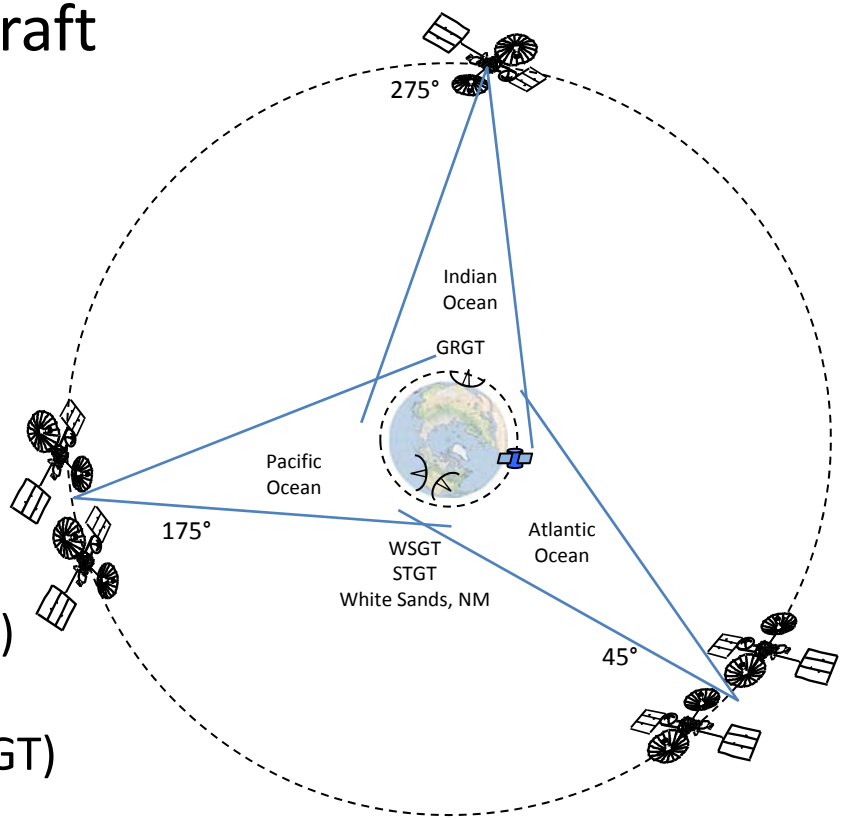
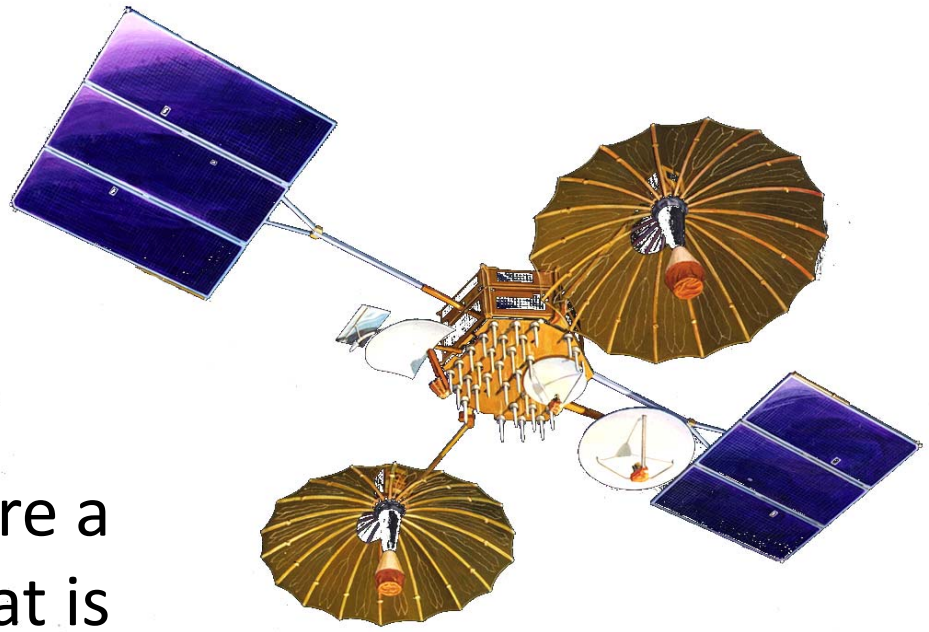
TDRSS Full Coverage

- NASA's Tracking and Data Relay Satellite System (TDRSS) has multiple communication relay satellites in geostationary orbits with the ability to provide continual contact with low-earth spacecraft
- ISS communication is a prime user of this capability
- Other missions use scheduled blocks of time
- Each TDRS can support data rates up to 300 Mbps
- Ground terminals at:
  - White Sands Ground Terminal (WSGT)
  - Second TDRS Ground Terminal (STGT)
  - Guam Remote Ground Termina,l (GRGT)



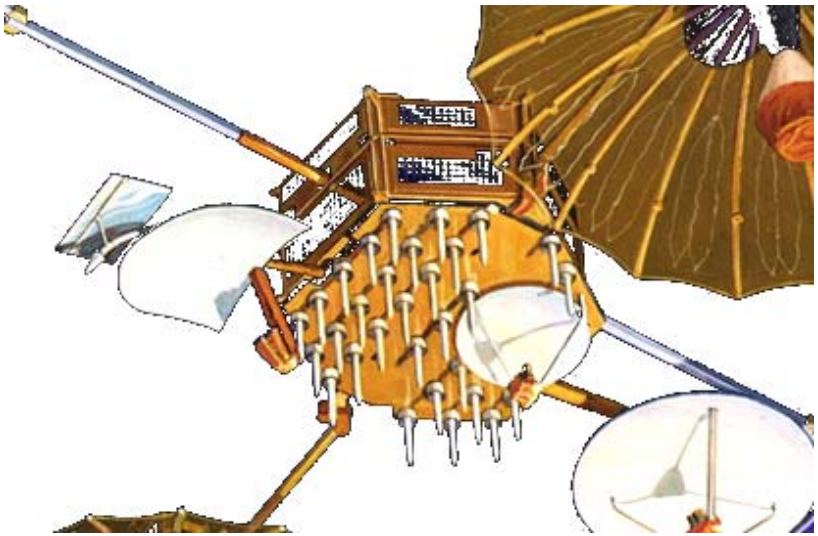
TDRS Antenna Systems

- Each TDRS has multiple antennas
- Two 5 meter steerable dishes provide high-rate communication support
- However, these dishes are a very limited resource that is carefully scheduled among users



- There are also 30 small multiple access antennas that can support many simultaneous users at lower rates

TDRS Multiple Access Service



- On most TDRS, the 30 signals from the MA antennas are all sent to the ground for further processing
- Ground equipment can then time shift and combine the signals to form multiple receive beams aimed in different directions
- This allows supporting many more users but at lower data rates of up to 300 Kbps per user
- MA service operates on an S-band frequency supporting simultaneous users with spread spectrum technology

TDRS Demand Access Service

- The TDRS Demand Access Service (DAS) is intended to support multiple users for long durations with the MA multiple beam capability
- Satellites looking for events like gamma ray bursts use DAS for continuous, low-rate communication
  - Many DAS users operate at 1 to 2 Kbps, but 24 hours a day
- NASA's Space Network (SN) is investigating options for supporting many more MA users such as cubesats
- However, the current DAS hardware only supports 5 simultaneous users for each TDRS even though the MA signals can be used to form many more beams
- The desire to make more use of the MA signals and support many more simultaneous users led to a study to investigate augmentation options

DAS Augmentation Concept

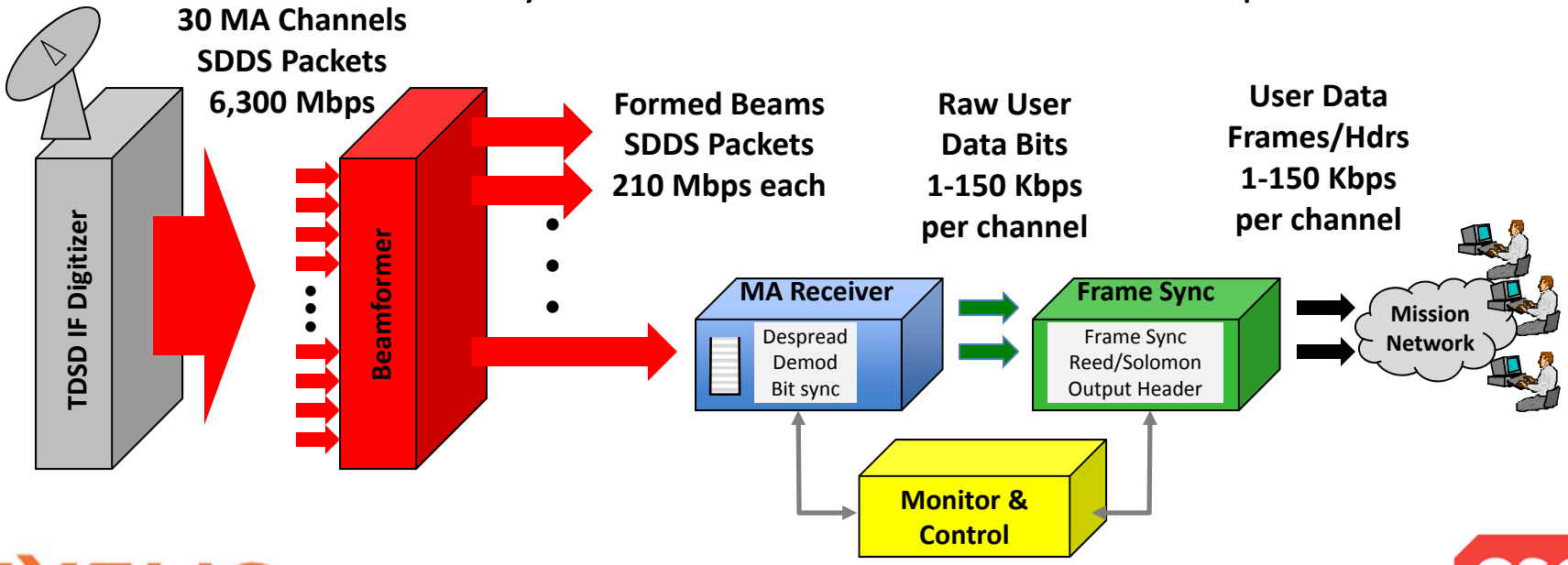
- With more DAS equipment, the SN could expand from 5 users to support 30 or more users on each TDRS
  - The MA signals are continually sent to the ground, just need processing
- More equipment would allow permanently configuring dedicated equipment strings for all DAS customers at all sites to eliminate all need for scheduling systems
  - DAS systems at all sites would continuously form beams, listen, collect, and forward any data received
  - Users would just send updated orbital state vectors weekly
  - Users could send requests to change data rates and some other settings
- This highly automated DAS system would be standalone and data driven with almost no legacy interfaces
- Increased capacity might be useful for missions such as cubesat communication and locating missing cubesats

Augmentation Key Components

- The key to DAS Augmentation is having enough low-cost resources to allocate dedicated equipment to each user at all sites
- Key components:
  - New beamformers to form more beams
    - Already installed as part of TDRS Digital Signal Distribution upgrade
    - Capable of forming 30 or more beams for each TDRS
  - Low-cost DAS receivers (~$1K per receiver)
    - Current receivers tend to cost $50K to $100K or more
  - Low-cost frame sync and user data formatting equipment
    - Software based, allows unlimited copies at minimal cost
- All DAS components NASA developed hardware and software with no unit level licensing/maintenance fees

Augmentation Key Components

- Data from TDRS antenna digitized at ground antenna
- Beamformer ingests MA streams, forms beams, outputs Signal Data Distribution Standard (SDDS) IF packets
- MA receivers despread, demodulate, remove coding, bit sync data, and outputs bits in UDP/IP packets
- Frame sync ingests bits, locates frames, Reed/Solomon processing, and outputs with specified user headers
- Monitor and control system monitors and commands components



TDRS Digital Signal Distribution

- TDSD already installed beamformers at all sites
  - Each TDSD beamformer can form 30 beams
  - STGT and WSGT each have 3 TDSD beamformers and each site has at least 2 TDRS's available for DAS
  - GRGT has 2 TDSD beamformers and a TDRS available
  - Each beamformer can access any TDRS at the site
- Each beamformer consists of a general purpose server and a custom FPGA system
  - The server handles monitor and control of the FPGA system and feeds TLE orbit information to the FPGA
  - The FPGA system receives 30 MA streams of SDDS packets at an aggregate rate of over 6 Gbps, uses configuration information sent to it to form beams, and outputs each beam as a stream of SDDS packets at 210 Mbps

Low-cost DAS Receivers

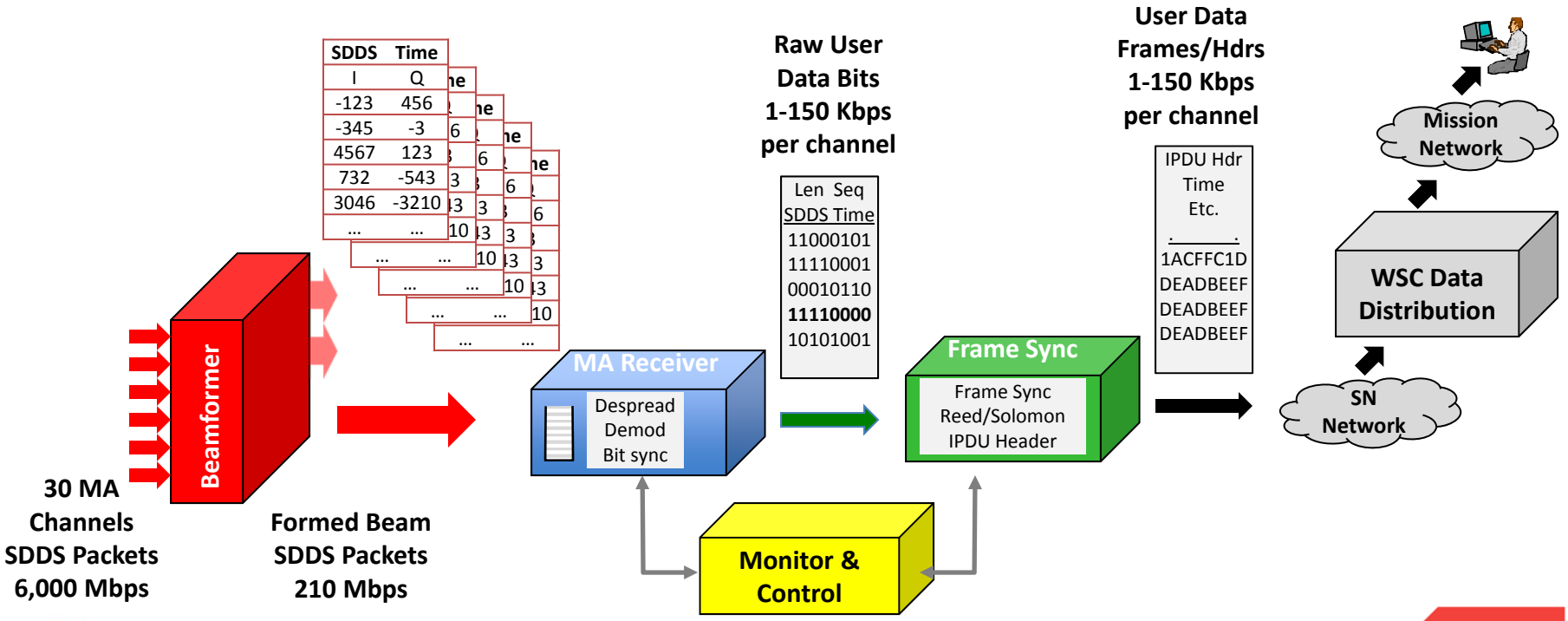
- Using 100 or more receivers requires low-cost receivers
- DAS receivers ingest TDSD SDDS packets at 210 Mbps and output packets of raw data bits
  - Ingest SDDS packets via UDP multicast on one Ethernet interface
  - Despread, demodulate, optional Viterbi, bit sync, time tag, and output the bits in UDP/IP packets on a second Ethernet interface
  - Receiver monitor and control also uses the second Ethernet interface
- Two prototypes being tested
  - FPGA based hardware receiver version
    - Up to 3 receivers in a 1U chassis (~$3K per chassis)
    - NASA owns the FPGA code
  - Software receiver version running on a multi-core server
    - Up to 4 receiver instances running in a 1U server
    - Software developed for NASA by Exelis

Software Frame Synchronizers

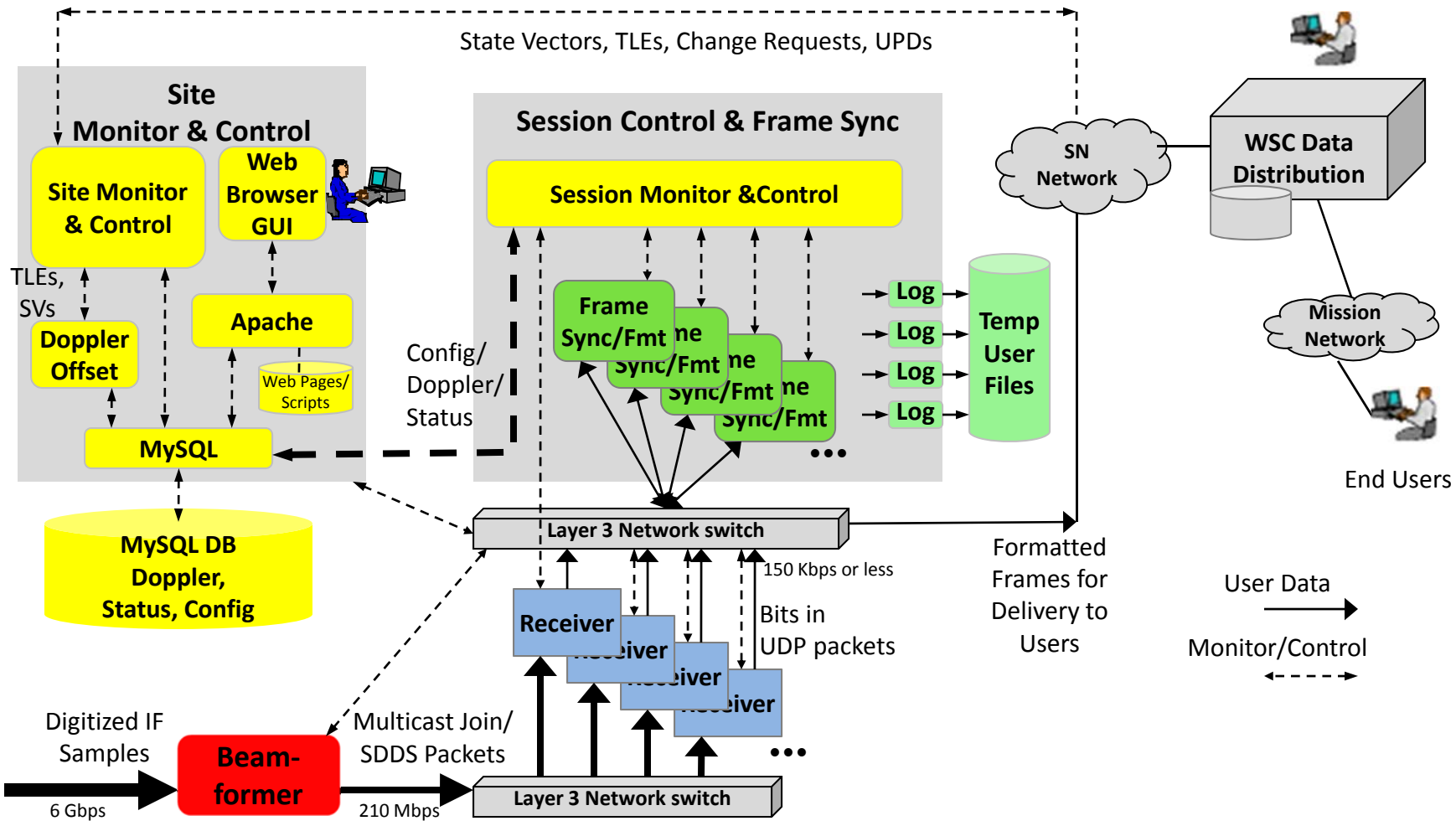
- Frame synchronization software receives raw bits, locates frame boundaries, inverts bits if necessary, extrapolates time, performs Reed/Solomon if present, adds user header and sends the packets
  - Software originally developed for Landsat in 1995
  - Software reused for SOHO, WIND, POLAR, GEOTAIL level-zero processing systems and control centers in 1998
- It can operate at multi megabit rates but only needs to handle up to 150 Kbps per stream for DAS.
  - Supports over 100 DAS data streams on one server
  - Uses 1% of one core at 150 Kbps random data

DAS Augmentation Data Flow

- Once IF signal is digitized at antenna, all other processing is digital over 1 Gbps and 10 Gbps Ethernet
- All equipment is connected using high performance layer 3 Ethernet switches passing data in UDP/IP packets using IP multicast and unicast



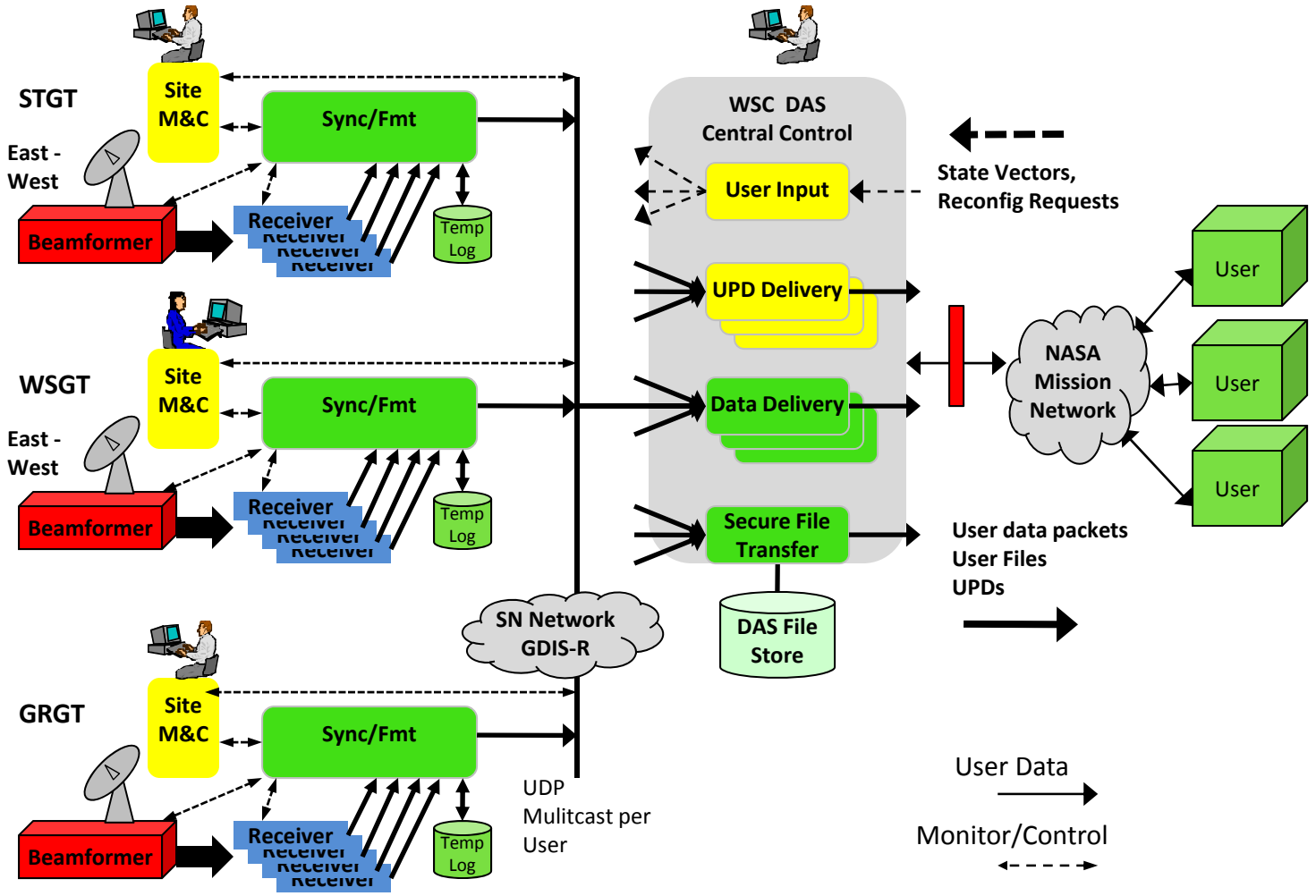
Single Site Architecture



Full System Architecture

- With each of the three TDRS ground stations augmented, a single site is still needed to provide a central point of contact for user control centers
- Central software processes at WSC will collect data from all sites and forward to users as appropriate
- User performance data (UPD) will be collected from all sites and forwarded to users
- It will also accept configuration change requests and user satellite orbit updates and provide them to all three DAS sites
- Archival data storage will also be provided by storing recorded data files from each DAS site

Full System Architecture



Current Status

- A prototype system is currently being tested to determine if the low-cost components can meet the DAS requirements
  - 3 software receivers
  - 3 hardware receivers
  - Frame sync server
  - Basic monitor and control
- Testing is being done at White Sands using test data radiated from a ground based transmitter
- Also shadowing orbiting spacecraft and comparing with the legacy DAS system
- Data is being collected to compare the performance of the low-cost receivers to the legacy ones

Summary

- A decision on whether to proceed with the full DAS Augmentation will be made when the current testing and analysis is complete
- Enhanced service options also being considered
  - Array multiple TDRS for signal gain to support spacecraft such as cubesats
    - Combine WSGT & STGT MA signals to recover weaker signals
    - Possible include GRGT by sending soft bits back to White Sands
  - Frame Relay/IP support
    - Spacecraft IP packets delivered direct to end users
  - Tracking Service using multiple MA services
    - Process multiple TDRS MA signals for triangulation
- More work to be done, but potential for supporting many more missions with low-cost, automated support