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AN OVERVIEW OF REFERENCE USER SERVICES DURING THE ATDRSS ERA

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ABSTRACT

The Tracking and Data Relay Satellite System (TDRSS) is an integral part of the overall NASA Space Network (SN) that will continue to evolve into the 1990's. As currently envisioned, the TDRSS space and ground segments will continue supporting the telecommunications and tracking needs of low-earth-orbiting (LEO) user spacecraft until the late 1990's. Projections for the first decade of the 21st century indicate the need for an SN evolution that must accommodate growth in the LEO user population and must further support the introduction of new/improved user services. A central ingredient of this evolution is an Advanced TDRSS (ATDRSS) follow-on to the current TDRSS that must initiate operations by the late 1990's in a manner that permits an orderly transition from the TDRSS to the ATDRSS era. In addition, the ATDRSS must interface with the remainder of the SN elements in a manner that simplifies user access to SN resources, while maximizing user flexibility in satisfying its mission requirements.

NASA is in the process of developing an SN/ATDRSS architectural and operational concept that will satisfy the above goals. To this date, an SN/ATDRSS baseline concept has been established that provides users with an "end-to-end data transport" (ENDAT) service characterized by the following fundamental features:

- A friendly interface with the SN that permits users to obtain services without in-depth knowledge required as to

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[1]Supported under contract by NASA/Goddard Space Flight Center

"how ATDRSS works".

- A transition from TDRSS to ATDRSS that is transparent to existing TDRSS users from an operational perspective, but leads to enhanced communications/tracking performance.

- Multiple grades of service that provide users with the flexibility to select an end-to-end service quality (including error-free operation) tailored to the specific mission requirements.

- Growth in the quantity of communication channels, commensurate with the growth in the user population.

- The provision of improved space-to-space RF link efficiency, thereby making ATDRSS support attractive to small users that are currently burdened by the LEO-to-TDRS propagation path.

- The introduction of data rates that exceed 300 Mbps, to permit satisfaction of evolving scientific requirements that may, for example, rely on the availability of digitized high-speed, high-definition TV.

- The application of advanced technologies/techniques that automatically mitigate external phenomena (such as RFI), thereby minimizing service schedule constraints and, hence, maximizing service availability.

Within the context of this baseline, additional service options are currently under investigation that can be readily incorporated with little or no perturbation to the baseline concept. One example is a user capability for autonomous LEO spacecraft navigation. A second example is the introduction of a near-real-time user access feature that potentially alleviates the existing long-lead scheduling process.

On the other hand, potential user services have been identified that are not supportable by the baseline. Most notable here are closure of the zone-of-exclusion (ZOE) and the distribution of data directly from the ATDRS to user premise terminals outside of White Sands. The baseline concept intentionally excludes these features because, to this date, no user requirement has been identified that justifies the associated increase in complexity and cost.

This paper provides an expanded description of the baseline ENDAT concept, from the user perspective, with special emphasis on the TDRSS/ATDRSS evolution. The paper begins with a high-level description of the end-to-end system that identifies the role of ATDRSS; also included is a description of the baseline ATDRSS architecture and its relationship with the TDRSS 1996 baseline. Other key features of the ENDAT service are then expanded upon, including the multiple grades of service, and the RF telecommunications/tracking services to be available. The paper concludes with a description of ATDRSS service options.

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OUTLINE

=======> ● ATDRSS DRIVERS AND OBJECTIVES

● ATDRSS ROLE WITHIN END-TO-END USER SYSTEM

● OVERVIEW OF END-TO-END SERVICES

● ATDRSS SERVICE OPTIONS

● SUMMARY

WHY ATDRSS?

- TDRSS WILL SATISFY SPACE NETWORK (SN) REQUIREMENTS TO THE LATE 1990's

- ADVANCED TDRSS (ATDRSS) MUST ACCOMMODATE GROWTH IN USER-POPULATION/SERVICE-REQUIREMENTS DURING POST-TDRSS ERA

  - ATDRSS INITIATION BY LATE 1990's
  - ORDERLY TDRSS/ATDRSS OPERATIONS CONCEPT EVOLUTION
  - ATDRSS OPERATIONS THROUGH ~2010

USER SERVICE SUPPORT - ACCOMMODATED BY SN/ATDRSS BASELINE

PRINCIPAL DRIVERS

- USER END-TO-END DATA TRANSPORT SERVICE
- SIMPLIFIED/FRIENDLY USER INTERFACE WITH SN
- GROWTH IN QUANTITY OF COMMUNICATION CHANNELS
- MAXIMIZATION OF SERVICE AVAILABILITY
- TDRSS/ATDRSS TRANSITION TRANSPARENCY
- IMPROVED LINK EFFICIENCY
  - ESPECIALLY FOR SMALL, LOW PRIORITY USERS
- DATA RATE EVOLUTION BEYOND 300 MBPS
- RFI-IMPACT MINIMIZATION

OPTIONS

- NEAR-REAL-TIME (DEMAND) USER ACCESS
  - ALLEVIATES LONG-LEAD-TIME SCHEDULING PROCESS
- CONTINUOUS/UNSCHEDULED/AUTONOMOUS NAVIGATION
- $\geq$ 2 USERS IN CLOSE PROXIMITY OPERATIONS
- VIDEO/AUDIO DATA LATENCY, REDUCE TO 600 MS (ROUND TRIP)

USER SERVICE SUPPORT - NOT ACCOMMODATED BY SN/ATDRSS BASELINE

- SERVICES NOT ACCOMMODATED
  - ZOE CLOSURE
  - DIRECT DATA DISTRIBUTION TO USER PREMISE TERMINALS

- RATIONALE: ABSENCE OF SN OR USER REQUIREMENT

- ABOVE SERVICES ARE OPTIONS THAT ARE SUPPORTABLE VIA ATDRSS BASELINE ENHANCEMENTS
  - ENHANCEMENT, HOWEVER, DEPENDS ON DEMONSTRATION OF NEED

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- OVERVIEW OF END-TO-END SERVICES
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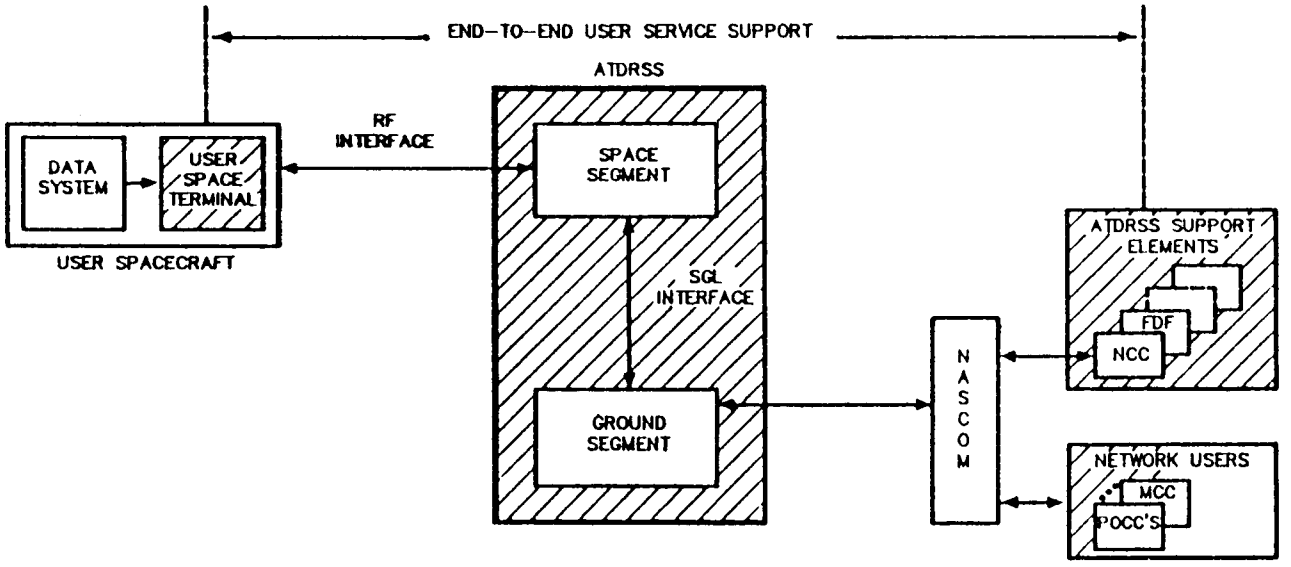
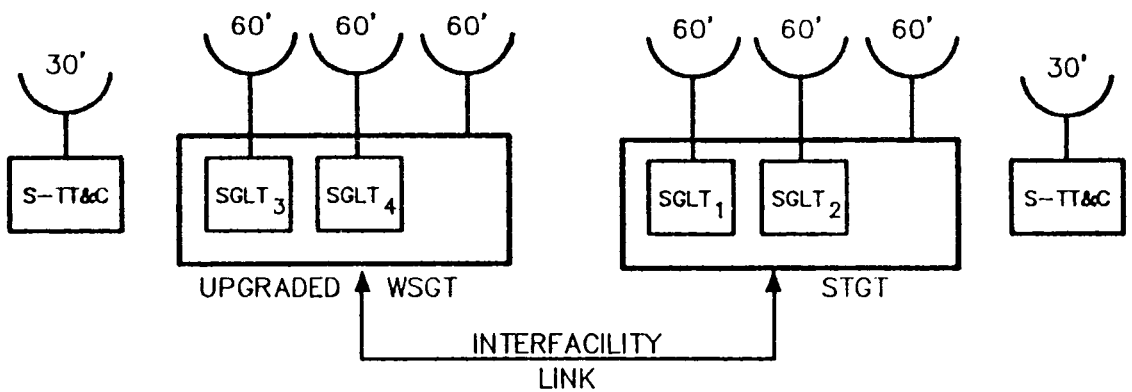
SN/ATDRSS END-TO-END SERVICE CONCEPT

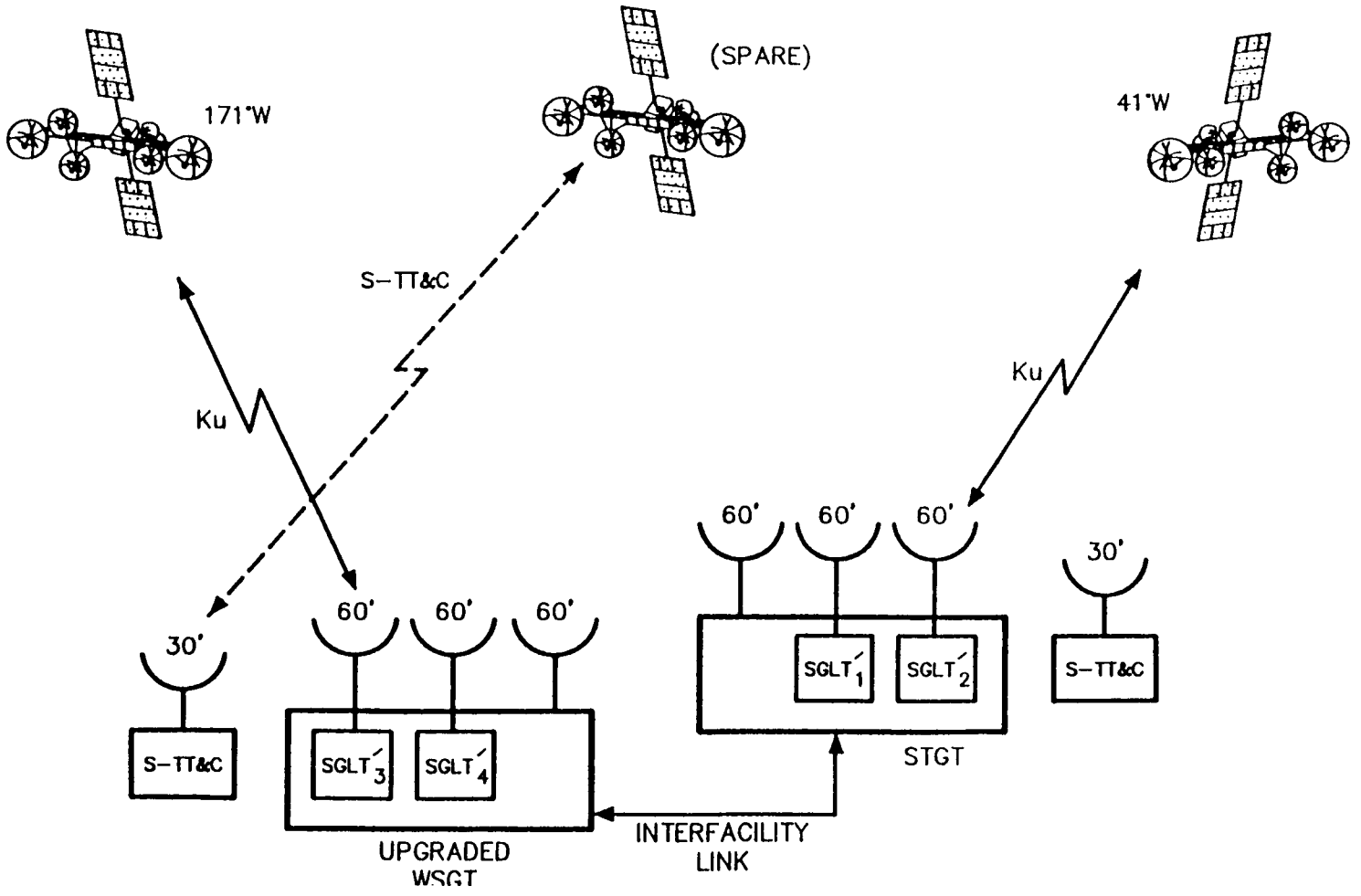


TDRSS BASELINE ARCHITECTURE

– 1996 POSTURE



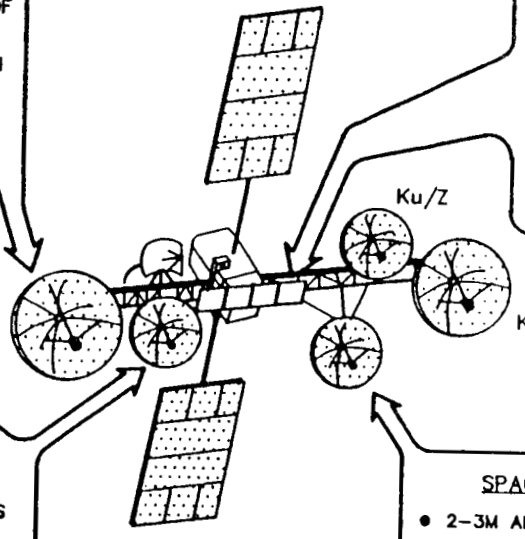
REFERENCE ATDRSS ARCHITECTURE



ATDRSS FEATURES

- ENCOMPASSES ALL TDRSS COMMUNICATIONS/TRACKING SERVICES
- INTRODUCES NEW/IMPROVED COMMUNICATIONS/TRACKING SERVICES
- FEWER ATDRSS S/C, LEADS TO SCHEDULING COMPLEXITY REDUCTION
- SUPPORTS SIMULATION AND TESTING
- TDRSS/ATDRSS TRANSITION IS TRANSPARENT FROM "TDRSS-USER" SERVICE PERSPECTIVE
- ATDRSS ARCHITECTURE/OPS CONCEPT SUFFICIENTLY FLEXIBLE TO PERMIT CONTINUED INTRODUCTION OF NEW/IMPROVED SERVICES DURING ATDRSS ERA

ATDRSS SPACECRAFT–REFERENCE FUNCTIONAL CONFIGURATION



DUAL S/Ku SERVICE

- 4.9M ANTENNA
- 1 OF 2
- SUPPORTS CONTINUATION OF EXISTING S/Ku SERVICE
- INCREASED SA LINK MARGIN (ESPECIALLY KSA) VIA STATE–OF–THE–ART TECHNOLOGY

ENHANCED SMA

- 151 ELEMENTS
  - SMA/SSA LINK COMPARABILITY
- ON–BOARD BEAMFORMING
  - 6 CHANNELS, RETURN
  - 2 CHANNELS, FORWARD
- DATA RATES
  - ≤3 MPBS, RETURN
  - ≤10 KBPS, FORWARD
- REDUCED SGL BANDWIDTH
- OPTION: INCLUDES SINGLE BEACON ELEMENT TO SUPPORT
  - AUTONOMOUS USER NAVIGATION
  - NETWORK TIME/FREQUENCY SYNCHRONIZATION
  - ATDRS ORBIT DETERMINATION

DUAL Ku/Z SERVICE

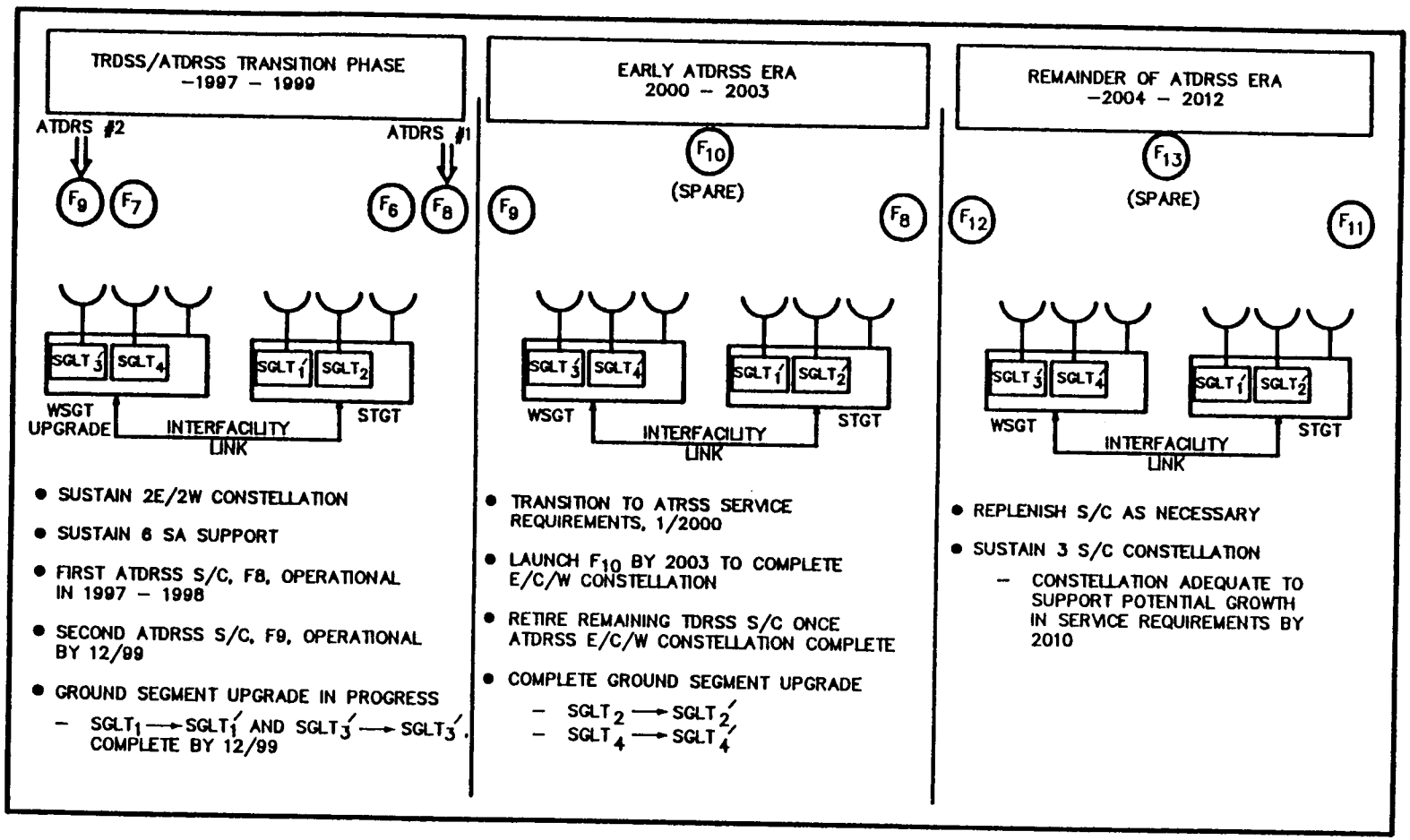
- 3–4.9M ANTENNA
- 1 OF 2
- SUPPORTS TRANSITIONAL KSA USERS WITH LINK QUALITY MEETING OR EXCEEDING TDRS KSA
- ZSA = KaSA OR WSA (TBR)
  - RETURN LINK DATA RATE INCREASE TO 650 MBPS
  - UP TO 9 dB LINK ENHANCEMENT RELATIVE TO TDRSS KSA

SPACE/GROUND LINK (SGL)

- 2–3M ANTENNA
- SINGLE–FEED @ Ku–BAND
- DUAL–POLARIZATION/FREQUENCY–REUSE

ATDRS

ILLUSTRATIVE TDRSS/ATDRSS EVOLUTION



OUTLINE

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- ATDRSS ROLE WITHIN END-TO-END USER SYSTEM
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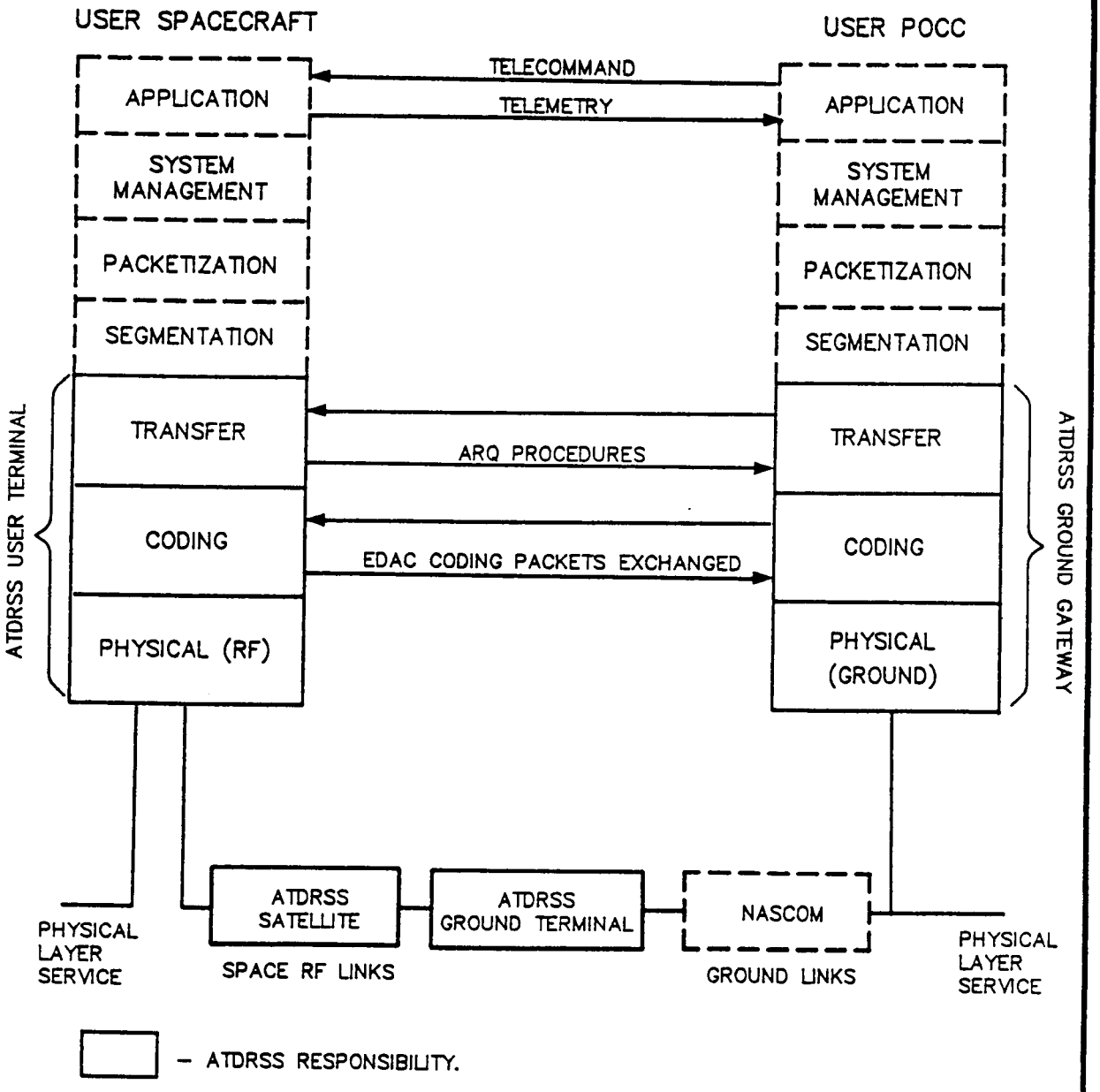
ATDRSS LOW DATA RATE SERVICE MODEL



SN/ATDRSS END-TO-END SERVICES

- END-TO-END SERVICE CONCEPT PROVIDES RELIABLE/STANDARDIZED/USER-FRIENDLY ACCESS TO SN

- CCSDS STANDARDS/PROTOCOLS SERVE AS REFERENCES FOR SPECIFICATION OF END-TO-END SERVICES

  - KEY CCSDS SPONSORS: NASA, ESA, NASDA

- LAYERED ATDRSS SERVICE MODEL

GRADES OF SERVICE

- 2 UNFORMATTED AND 3 FORMATTED GRADES OF SERVICE

- UNFORMATTED PHYSICAL LAYER SERVICE
  - TRANSPORT OF UNFORMATTED DATA BETWEEN POCC AND USER SPACE TERMINAL
  - UNCODED OR CONVOLUTIONALLY CODED
  - SAME AS CURRENT TDRSS

- FORMATTED SERVICE (CCSDS): END-TO-END DATA TRANSPORT VIA THREE GRADES OF PACKET-FORMATTED SERVICE
  - GRADE 1: ERROR-FREE, BLOCK-CODED, ERROR-DETECTION/CORRECTION, AUTOMATIC REPEAT REQUEST (ARQ)
    -- E.G., SATELLITE COMMAND UPLOADING
  - GRADE 2: BLOCK-CODED, ERROR-DETECTION/CORRECTION
    -- E.G., COMPRESSED VIDEO
  - GRADE 3: NO BLOCK CODING
  - EACH GRADE OF FORMATTED SERVICE IS TRANSMITTED VIA PHYSICAL LAYER SERVICE

TELEMETRY SERVICE DATA QUALITY REQUIREMENTS

GRADE OF SERVICE	FORMATTED SERVICE GRADE			PHYSICAL LAYER SERVICE GRADE	
	1	2	3	A (CODED)	B (UNCODED)
DATA COMPLETENESS GUARANTEED	YES	NO	NO	NO	NO
BIT ERROR RATE[1]	10^{-12}	10^{-8}	10^{-5}	10^{-5} [2]	10^{-5} [3] (TBR)
IN-SEQUENCE GUARANTEED	YES	NO	NO	N/A	N/A
DUPLICATES POSSIBLE	NO	YES	YES	NO	NO
DELIVERY OF NON-CORRECTABLE ERRORS TO USER	NO	YES	N/A	N/A	N/A
IDENTIFICATION OF NON-CORRECTABLE ERRORS TO USER	NO	YES	N/A	N/A	N/A

NOTES

1. BIT ERROR RATES INCLUDE THE OCCURRENCE OF DETECTED AND UNCORRECTED ERRORS DELIVERED TO THE USER.
2. S-BAND SERVICE ONLY.
3. KU AND Z-BAND SERVICE ONLY.

TB880146/VGP4AW-2/JLT/4-14-88

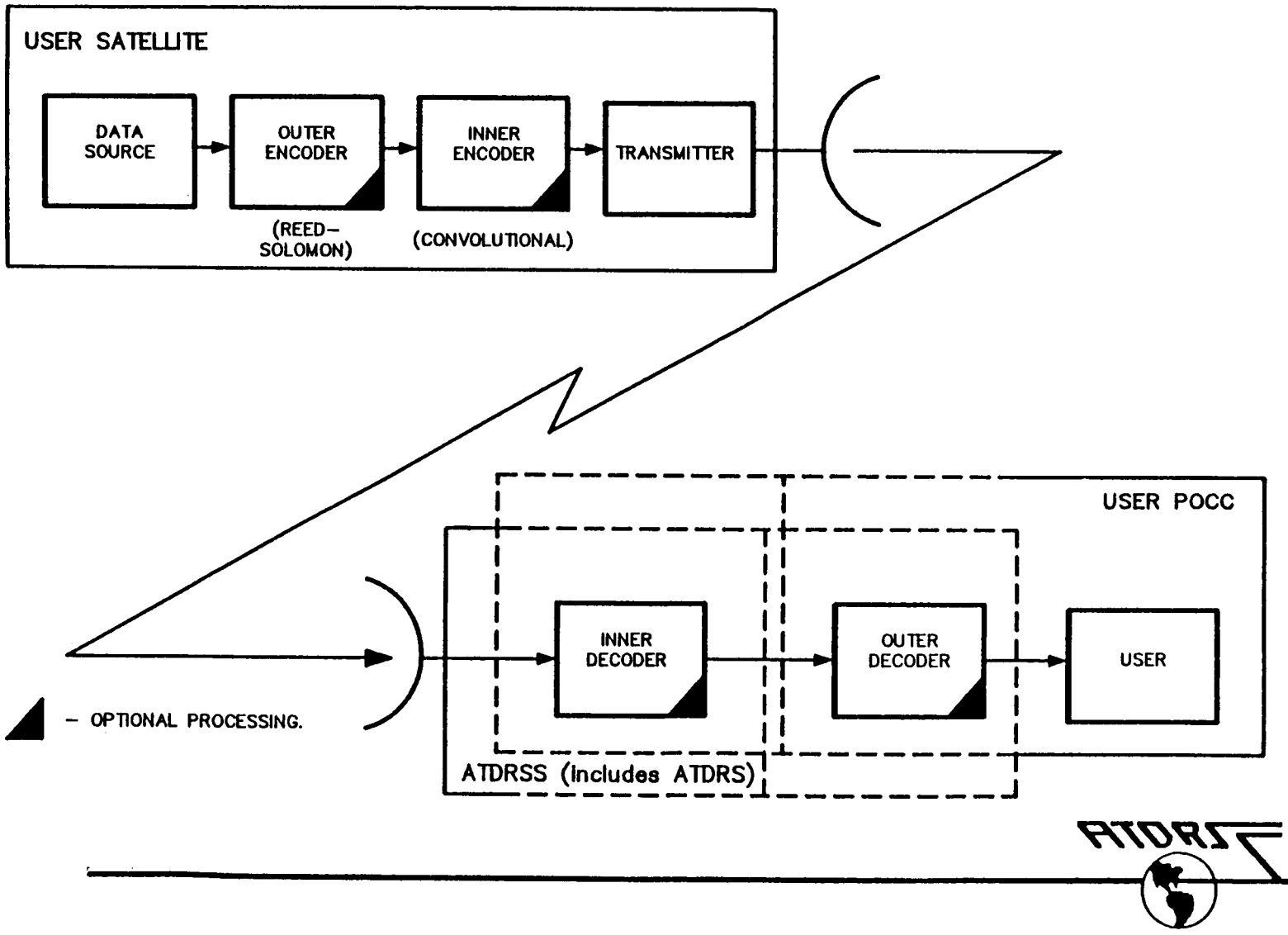
ATDRSS COMMUNICATIONS/TRACKING SERVICES*

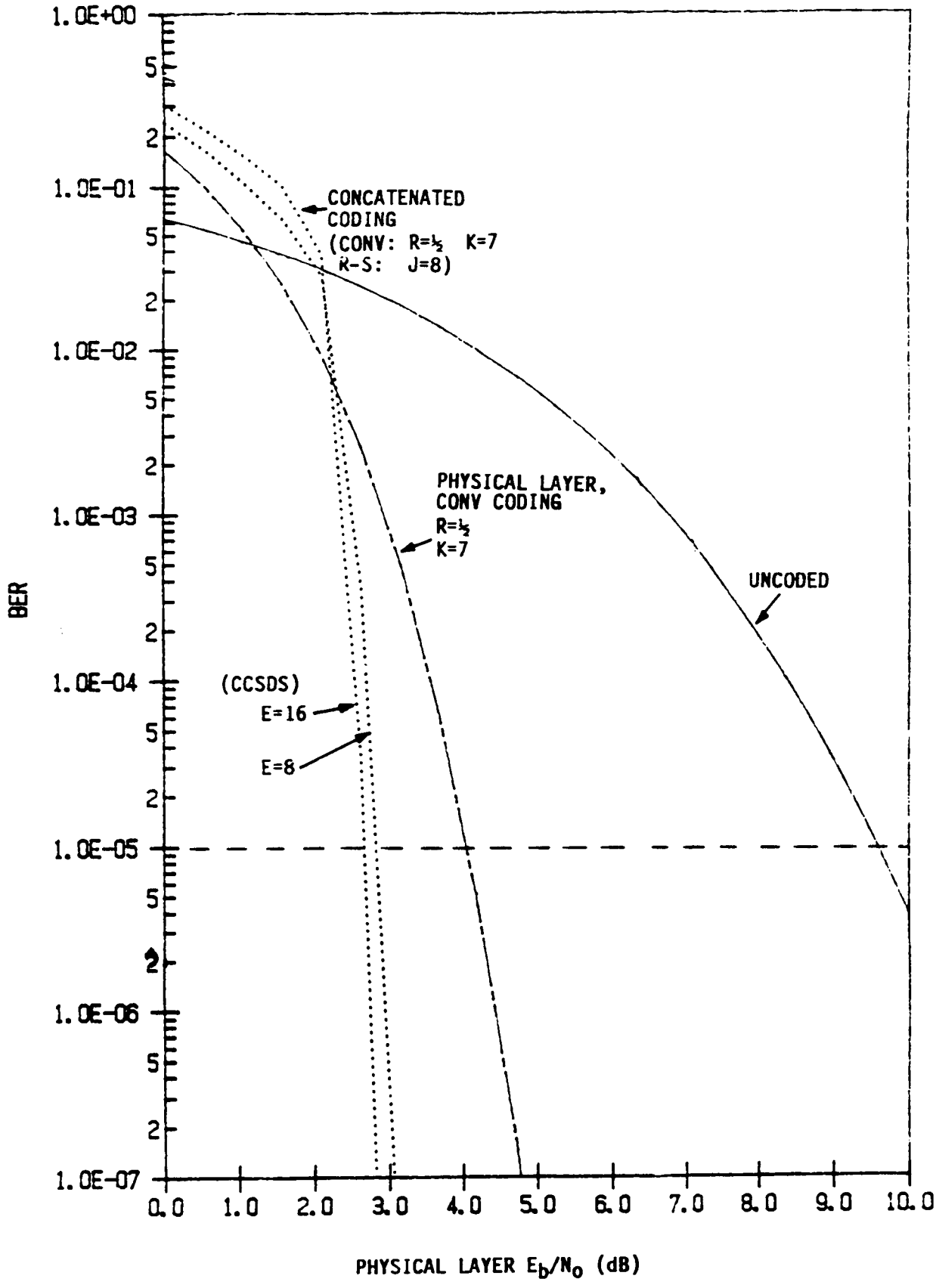
FEATURE \ SERVICE		ENHANCED SMA (EMA)	SSA	KSA	NEW HIGH DATA RATE SA (K_ASA OR WSA)
TDRSS DATA RATES RETAINED	FORWARD/ TELE-COMMAND	≤10 KBPS	• ≤300 KBPS • SHUTTLE-UNIQUE	• ≤25 MBPS • SHUTTLE-UNIQUE	—
	RETURN/ TELEMETRY	≤50 KBPS	• ≤6 MBPS • SHUTTLE-UNIQUE	• ≤300 MBPS • SHUTTLE-UNIQUE	—
NEW DATA RATES INTRO-DUCED	FORWARD/ TELE-COMMAND	—	—	• ≤50 MBPS	≤50 MBPS
	RETURN/ TELEMETRY	• ≤300 KBPS, PN • ≤3 MBPS, NO PN	—	—	≤650 MBPS
LINK QUALITY ENHANCEMENT GOALS ON PHYSICAL LAYER RELATIVE TO COMPARABLE TDRSS SERVICE		• NONE, FORWARD • 9 dB, RETURN (PROVIDES SSA LINK QUALITY)	NONE	• 3 dB, FORWARD • 4 dB, RETURN	RELATIVE TO KSA • 3 dB, FORWARD • RETURN - 9 dB, K_A SA - 8 dB, WSA
CARRIER		• 2106.4, FORWARD • 2287.5, RETURN	TUNABLE • 2030-2113, FORWARD • 2205-2295, RETURN	• 13775, FORWARD • 15003, RETURN	TBD
QUANTITY OF CHANNELS (SYSTEM)		• 4, FORWARD • 12, RETURN	4, FULL DUPLEX	8, FULL DUPLEX	4, FULL DUPLEX
SCHEDULED TRACKING SERVICES		• TWO-WAY - RANGE - DOPPLER • ONE-WAY RETURN - NONCOHERENT DOPPLER • TIME TRANSFER	→	→	→

* 2 ATDRS CONFIGURATION

TB880146/VGP4AW-1/JLT/4-14-88

CONCATENATED CODING PROVIDES PROCESSING FLEXIBILITY FOR ATDRSS





ILLUSTRATIVE CONCATENATED CODING PERFORMANCE

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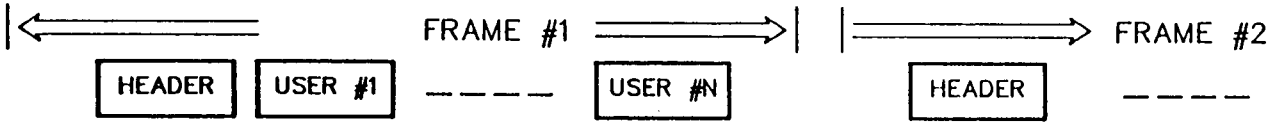
REPRESENTATIVE SERVICE OPTIONS

- FULL-DUPLEX OPERATION FOR ALL EMA USERS
- NAVIGATION BEACON
- NEAR-REAL-TIME SERVICE ACCESS
- CLOSE-PROXIMITY OPERATIONS

EMA OPTION, FULL–DUPLEX SUPPORT TO ALL MA UERS

- EMA CAPABILITY PER S/C
  - 6 RETURN CHANNELS
  - 2 FORWARD CHANNELS
- UTILIZATION OF FORWARD CHANNELS
  - 1 CHANNEL PROVIDES DEDICATED SUPPORT TO ONE USER AT A TIME
    - SUPPORTS TDRSS MA USERS DURING TRANSITION
    - SUPPORTS UNIQUE USER NEEDS (e.g., COHERENT, 2–WAY TRACKING AND TIME TRANSFER)
  - TDM LINK VIA SECOND CHANNEL PROVIDES "CONTINUOUS" FORWARD CHANNELS TO EQUIPPED USERS

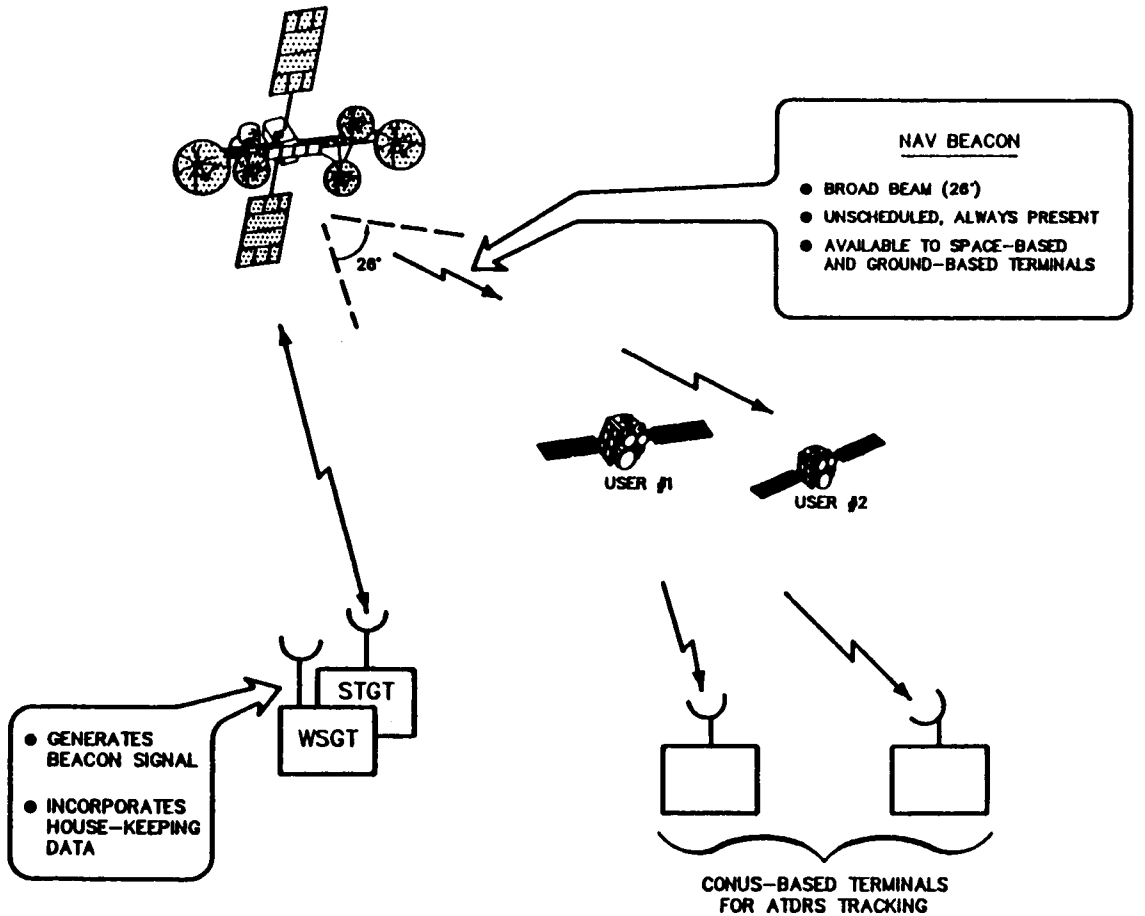


    - HEADER PROVIDES ORDERWIRE INFORMATION
    - 10 KBPS BURST DATA RATE
    - 100 MS AVERAGE BURST PER USER
    - ≥1–2 KBPS EFFECTIVE, CONTINUOUS DATA RATE PER USER
    - TRACKING REQUIREMENTS SATISFIED VIA COMBINATION OF NAVIGATION BEACON, ONE–WAY RETURN DOPPLER, PERIODIC UTILIZATION OF DEDICATED FORWARD CHANNEL
  - TWO–CHANNEL COMBINATION READILY SUPPORTS FULL–DUPLEX SERVICE FOR 6 USERS PER ATDRSS S/C

NAVIGATION BEACON OPTION

- BEACON TRANSMISSION VIA SINGLE S-BAND ELEMENT OF SMA ARRAY
  - 26° BEAMWIDTH
  - Ku-BAND BEACON ALSO UNDER CONSIDERATION
- AUTONOMOUS USER S/C NAVIGATION
  - PRIMARY OR BACKUP
- SIMULTANEOUSLY PROVIDES CONUS-BASED ATDRS TRACKING
- UNSCHEDULED, ALWAYS PRESENT
- SATISFIES MOST USERS
  - $\leq$ 50 METERS READILY ACHIEVED
  - 10 METERS, POTENTIAL
- PROVIDES HOUSEKEEPING DATA
  - POTENTIALLY OFFERS BUILT-IN CAPABILITY FOR DEMAND ACCESS

NAVIGATION–BEACON OVERVIEW

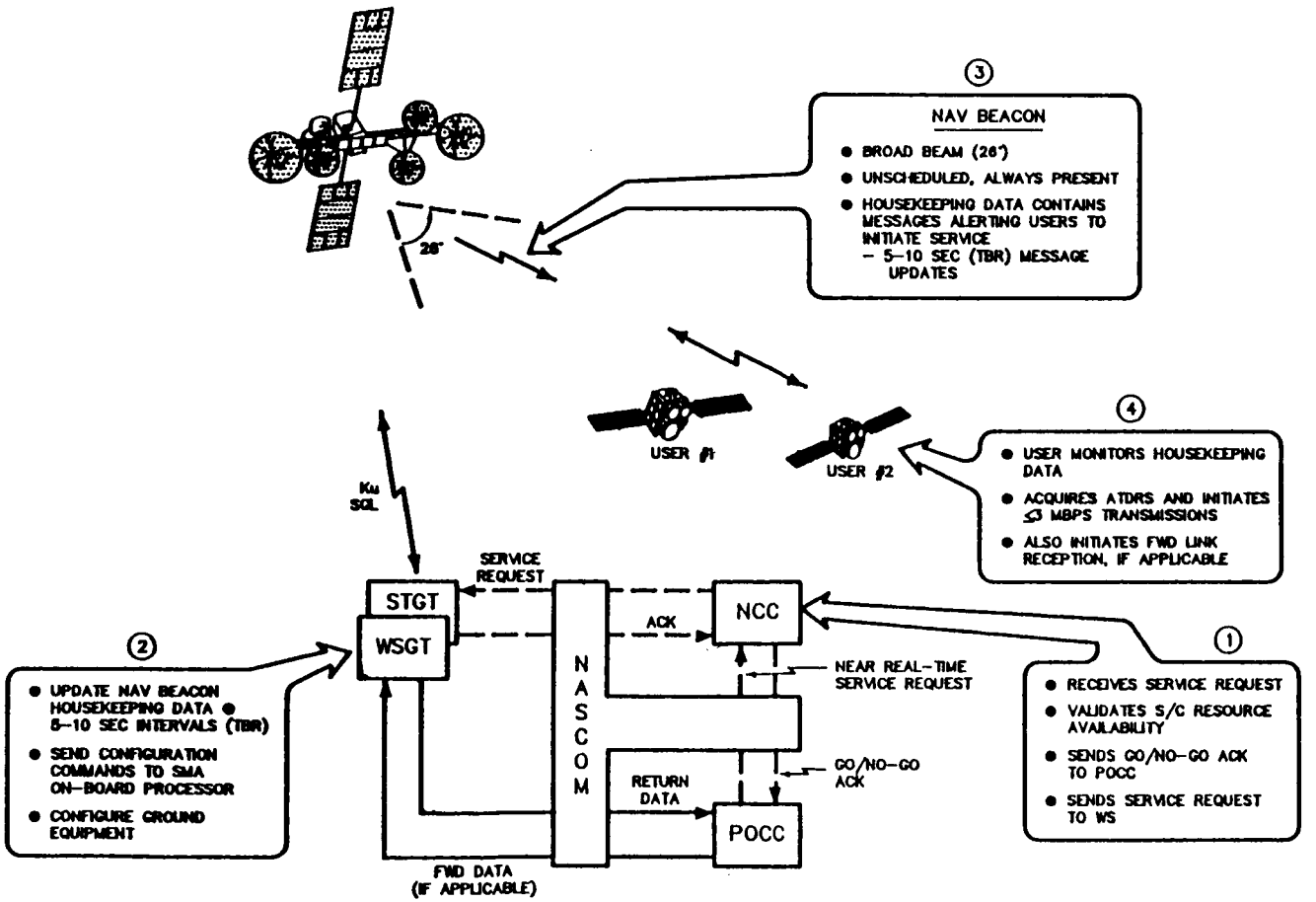


NEAR-REAL-TIME SERVICE ACCESS OPTION

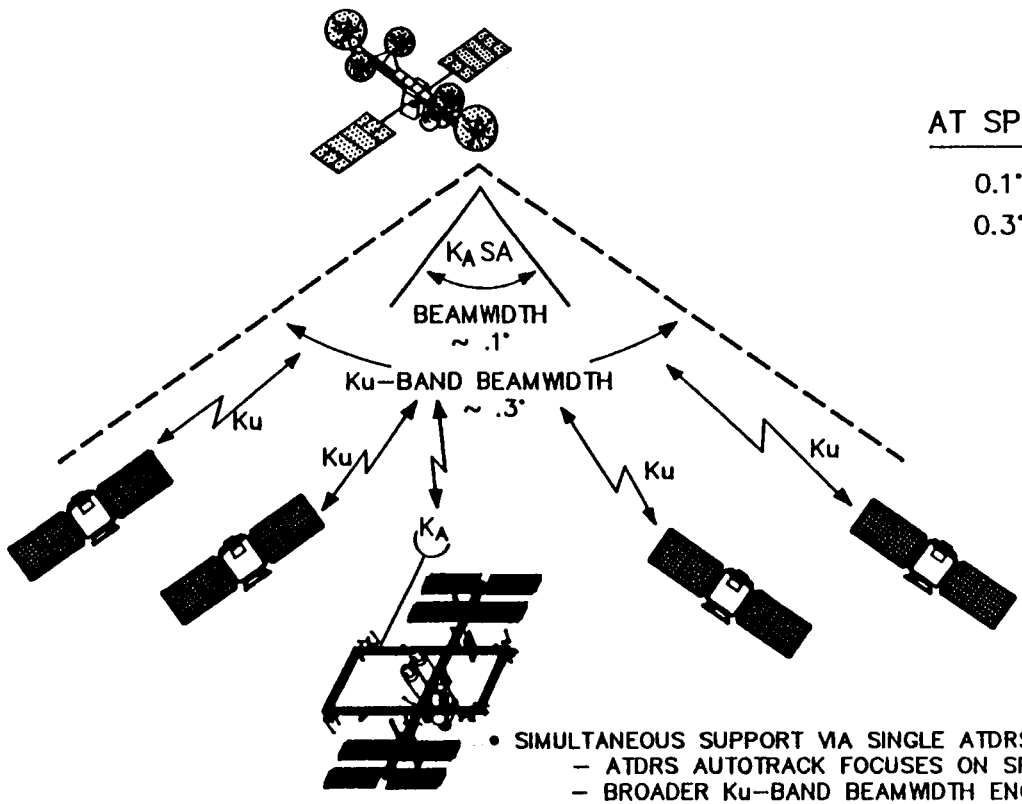
- DEFINITION: OBTAINING "RAPID" ATDRSS SERVICE WITHOUT REQUIRING USE OF THE FORMAL, LONG-LEAD SCHEDULING PROCESS

- USAGE: ACCOMMODATE UNPLANNED/UNSCHEDULED USER SERVICE NEEDS; MAXIMIZE USER OPERATIONAL FLEXIBILITY

ILLUSTRATIVE NEAR-REAL-TIME-ACCESS SCENARIO



ILLUSTRATIVE CLOSE PROXIMITY OPERATIONS



AT SPACE STATION ALTITUDE:

0.1° ~ 70 km FOOTPRINT
0.3° ~ 200 km FOOTPRINT

- SIMULTANEOUS SUPPORT VIA SINGLE ATDRS Ku/K_A ANTENNA
  - ATDRS AUTOTRACK FOCUSES ON SPACE STATION
  - BROADER Ku–BAND BEAMWIDTH ENCOMPASSES OTHER CLOSE–PROXIMITY USERS
- SPACE STATION
  - FORWARD DATA RATE $\leq$ 50 Mbps (e.g., 2 TV CHANNELS)
  - RETURN DATA RATE, 650 Mbps (POSSIBLY HIGHER)
- AT LEAST 4 ADDITIONAL USERS
  - FDM THROUGH SINGLE KSA CHANNEL (225 MHz)
  - RETURN DATA RATE PER USER $\leq$ 25 Mbps (e.g., 1 TV CHANNEL)

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SUMMARY

- EVOLUTION TO ATDRSS WILL OCCUR BY THE LATE 1990's
- TRANSITIONAL TRANSPARENCY FROM "TDRSS-USER" PERSPECTIVE
- ATDRSS WILL BE AN INTEGRAL PART OF END-TO-END USER DATA TRANSPORT SYSTEM
  - CCSDS STANDARDS/PROTOCOLS
  - MULTIPLE GRADES OF SERVICE
  - NEW/IMPROVED COMMUNICATIONS/TRACKING SERVICES
  - SIMPLIFIED/FRIENDLY USER INTERFACE WITH SN
- MULTIPLE SERVICE OPTIONS CAN BE ACCOMMODATED BY BASELINE ATDRSS ARCHITECTURE
- ZOE CLOSURE AND DIRECT DATA DISTRIBUTION CANNOT BE ACCOMMODATED BY BASELINE ARCHITECTURE
  - NEAR-TERM DECISION(S) REQUIRED