ARTS OVERVIEW

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1. ABSTRACT

Modernizing labor intensive Remote Tracking Station (RTS), increasing individual station capacity, and providing interoperable links between three separate Air Force satellite networks are the objectives of the Automated RTS (ARTS) program.
(Viewgraph #1, Title/Logo)

2. INTRODUCTION

The Air Force has operated a multisatellite control facility (AFSCF) for over twenty years. In 1980, IBM was contracted to modernize the data systems of the AFSCF. The DSM contract is due for completion in the 1987 time frame. This year the Air Force has contracted with Ford Aerospace to modernize the AFSCF tracking stations to complement the projected DSM capability and to make the RTS interoperable with the Global Positioning System (GPS) and the Defense Meteorological Satellite Program (DMSP) networks. The first phase of ARTS is due for completion in 1988. This paper provides a technical description of ARTS and a current status of the project.
(Viewgraph #2, Organization)

The ARTS program has been assigned to Ford Aerospace's Sunnyvale Operations (SVO). The SVO was selected because of its knowledge of multiuser, multisatellite operations, and its experience in servicing the current AFSCF network. SVO is basically a systems engineering, integration, and services facility. Early on trade studies selected companies with state-of-the-art, off-the-shelf products and technologies applicable to ARTS. The four areas and selected team members are:

Antenna and Antenna Control Systems - Datron Systems, Inc.
SGLS Downlink & Unlink Systems - Stanford Telecommunications, Inc.
Solid State High Power Amplifier Systems - Loral Data Systems

Automation (Control & Status) Systems - HRB Singer
(Viewgraph #3, Ford Aerospace Team)

3. BACKGROUND

ARTS is probably the last generation of ground stations as we recognize them today. It's projected life span (20 years) should see the perfection and implementation of intersatellite relay services. This development will change the role and scope of a world wide tracking network, perhaps obviating all but emergency use of overseas ground stations. In bridging the current and future technologies ARTS automates a multiuser network and links specialized networks. These are the precursor functions of future networks. The top level systems requirements for ARTS may be summarized into Manning, Capability, Schedule and (transparent) Interoperability.
(Viewgraph #4, Typical Station Manning)

A primary system requirement is to reduce the labor intensity at current SCF stations. At the Vandenberg Tracking Station (VTS) the current staff for 24 hours per day, seven day week manning is 121 people for all station functions: operations, maintenance, logistics, communications, etc. This is a two-sided RTS, i.e., two separate satellite support operations may run simultaneously. VTS currently has it's own data processing capability. If the data processing functions are moved to the STC, as will be the case in DSM, the VTS manning is reduced to 77. (The net savings of such a move depends on DSM staffing needed to pick up those DP functions.) VTS would thus become a "bent-pipe" station. Under ARTS, the staffing is further reduced to a station need of approximately 30 people. This is achieved through automation requiring no operator interface when the AFSCN is controlling the station remotely. When ARTS is in local automatic mode, a single operator console is all that is required to remotely configure the station for a pass. Once set-up, the status tests itself and completes the pass under process control.
(Viewgraph #5, Readiness Times)

ARTS upgrades station capability by increasing commanding and telemetry data rates to the DSM level, and by increasing station availability. Currently, RTS's reconfigure a station in approximately fifteen minutes. The ARTS will reduce turn around times between passes to five minutes or less. As most passes are fifteen minutes or less in duration, this represents an almost two-fold increase in station availability. The third requirement to increase capacity involves two new stations (Colorado Springs (CTS), and the Northern European Station (NES)), and upgrading the current Thule: Greenland station.
(Viewgraph #6, The AFSCN)

The AFSCN as seen from an ARTS perspective is scheduled for implementation in two phases. The first comprises the CTS, NES, TTS-A and an ARTS Development and

Maintenance Facility (ADMF) in Sunnyvale, California. The three stations and the ADMF are to be remotely controlled initially by the Satellite Test Center in Sunnyvale and subsequenth by the CSOC in Colorado Springs, Ca. All four sites will be installed and operational by June 1989. The second phase, also competitive, will start in 1987 with a planned replacement of the remaining RTS's. This should be completed in the early to mid 1990's.

Interoperability between networks has long been a DoD goal. In Phase I of ARTS the CTS will be automatically configured to look functionally like a GA station to the GPS control center. Likewise the TTS-B station will be configurable to look functionally like a DMSP remote station. In both cases it is incumbent on ARTS to require no special hardware or software interface at the other networks control centers.

Partially due to interoperability requirements ARTS will operate in one of three modes: Remote automatic, Local automatic or Manual. Remote means the MCC is sending configuration commands from STC, CSOC, DMSP or the GPS and there is no operator intervention. Local automatic means configuration instructions are relayed by voice from STC, CSOC, GPS or DMSP to the ARTS operator. Normally, the operator will use a pre-recorded disk to input the bulk of the data. In manual mode the individual subsystems may be operated manually by front panels or their equivalent.
(Viewgraph #7, System Schematic)

4. SYSTEM DESCRIPTION

a) **Core System**: ARTS is contractually divided into a core system, common to all sites, and enhancements which particularize a site for a given function. To this core system of TT&C, Control and Status, and Communications Interface is added an Antenna subsystem at each site except the ADMF. The core subsystems and the antenna overviews follow.
(Viewgraph #8, Antenna Subsystem)

Antenna: The antenna subsystem comprises the reflector, subreflector, feed, pedestal with drive components, controller and protective radome. The ARTS antenna is an update of a model supplied by Datron and currently in service at Thule as the Data Link Terminal. The reflector is 33' diameter disk with a surface tolerance that supports future operation at Ku-band. A six foot reflector mounted as an auxiliary aperture is a key input to the automated main beam acquisition (AMBA) system for improved sidelobe rejection. The feed is a single channel monopulse autotrack feed. This feed, coupled to a low-noise amplifier, provides a G/T of +22.4 dB/K at 2.2 GHz and a downlink performance margin of 1.4 dB. In the transmit mode the antenna produces an

EIRP of 105.6 dBm for an uplink margin of 0.6 dB. The antenna positioner is a dual drive, elevation over azimuth, designed for a 20-year life.

TT&C: ARTS will support SGLS and non-SGLS S-band tracking, health, and status telemetry, payload data, ranging and commanding services from Mission Control Centers (MCC's) in the STC or CSOC. ARTS will utilize acquisition data supplied in real time from an MCC to acquire a satellite. The TT&C subsystem must then generate and record tracking, range, and range rate data, as well as recording health and status and telemetry data. Telemetry may be in five separate streams of 250 b/s to 5.0 Mbps, while the SGLS downlink spectrum provides two RF carriers. Carrier I has a maximum of two subcarriers (1.24, 1.25 or 1.7 MHz) and Carrier II, located 5 MHz below contains biphase data from 128 Kb/s to 1024 Kb/s.

The TT&C CI features a third generation digital receiver, the performance of which exceeds all specification requirements, and which provides exceptional reliability: an MTBF of 8,700 hours. Moreover, the range and range rate measurements performed by this receiver include significant accuracy margins (0.1 feet RMS versus 5.0 feet RMS required and 0.01 ft/s versus 0.1 ft/s required). The receivers plus the data modulation, bit synchronization, signal strength calibration, baseband signal assembly, and RF carrier generation test equipment are all designed to be remotely controlled and statused. In addition, a unique combination of remotely controlled signal switching, splitting and attenuation hardware allow the many pieces of equipment in the TT&C CI to be pooled in a manner which greatly enhances their operational availability and which allows the CI to be rapidly and automatically reconfigured and tested. Another significant feature of the TT&C is the high power amplifier (HPA). The proposed HPA is a totally solid-state modular assembly with a nominal power output of 2250 W. The modules in the HPA are hosed upon a previously space qualified design, thereby addressing a major concern of the Government: HPA reliability. The proposed HPA has a predicted MTBF of over 86,000 hours compared with the ARTS requirement of 10,000 hours.
(Viewgraph #9, Automatic Remote Station Control)

Control and Status: The Ford Aerospace C&S incorporates a processor configuration based on a new Intel 286/310 system which incorporates the 1.0 MIP 286/10 CPU and 1 Mbyte of memory. Initially ARTS will require 150 KIPS and 0.3 Mbyte of memory. The power of the C&S Processor allows TT&C Controller and AMBA processing to be centralized within the C&S, thereby simplifying interfaces. The Timing Element of the C&S combines a GPS L1-band receiver with a single Rubidium standard in an integrated and compact design. This will provide timing that accurate to within 150 nanoseconds of US Naval Observatory time.

The use of auxiliary aperture amplitude comparison coupled with software centroid algorithm processing of amplitude-azimuth data after mainlobe detection is the approach selected for the ARTS automatic mainbeam acquisition. This combined approach offers the advantage of timely and positive mainlobe-versus-sidelobe discrimination plus the centroid algorithm advantage of mainlobe convergence after detection. The parameters for main antenna spatial search, receiver frequency search, and amplitude comparison dwells are selected to achieve a very high confidence of mainbeam detection of the satellite as it rises through the main beam search region. Consequently, a slower reduced scan width in azimuth through the detected main beam region, with appropriate elevation angle updating for satellite elevation motion during antenna recovery, will minimize elevation offset error from the actual satellite elevation angle. Previous performance studies have shown that an azimuth centroid, computed from successive, closely spaced amplitude samples taken during the return scan, can locate the satellite in azimuth to an accuracy well within the 3 dB TT&C antenna beamwidth.
(Viewgraph #10, Main Beam Acquisition)

If autotracking is the selected mode for the contact, the controller is directed to begin autotracking at the calculated position. When autotrack is achieved, acquisition is complete. If slave-bus tracking is the mode, AMBA offsets the slave-bus control mode. These procedures apply both to wideband and narrowband (SGLS coherent carrier I) acquisition scenarios. Throughout the process, the AMBA function sends status messages to the MMI function for operator display. These indicate the current state of acquisition and contain data calculated by AMBA such as SV position.

Communications Interfaces: All communications interfaces are provided GFE to ARTS. The ARTS digital interface to STC and CSOC is the currently installed AFSCF DSIS system. Current AP plans are to eventually provide the CSOC wideband communication equipments to ARTS. The GPS enhancement is colocated with CSOC at Colorado Springs, where their control system will be installed. The DMSP comm-interface is similar to the current one supported by the AFSCF tracking station at Hawaii. No significant risks are foreseen in any of these proven interfaces.
(Viewgraph #11, GPS Enhancement)

b) **GPS Enhancement**: The design of the GPS enhancement proposed by Ford Aerospace, when coupled to the ARTS Core and Government furnished communications equipment, will provide a functional equivalent to a GPS Ground Antenna (GA) site and will use existing GA software. This flexibility permits simultaneous communications between the CTS, and the AFSCF and the GPS Master Control Station (MCS). Moveover, this design retains the functional integrity of the ARTS Core configuration while also supporting all required GPS functions.

A table in the C&S processor will provide a memory map to equate GPS control directives to ARTS core system functions. In this way, the GFE software in the colocated GPS processor, an IBM Series 1, is untouched. New versions of that software will require no Series 1 recoding, and may or may not involve modifications to the memory map table.
Multiplexing of the Series 1 output ports takes place in an Intel microprocessor to minimize the isolation hardware that interferes the ARTS C&S. Red-Black separation within the enhancement is maintained by optical isolation of the Red Input/Output Controller (RIOC) and the Black Input/Output Controller (BIOC). Both the BIOC and the RIOC have embedded microprocessors which enabled changes in crypto gear configuration without impacting the Series 1 software.
(Viewgraph #12, DMSP: Bent Pipe or Local Commanding)

c) **DMSP Enhancement**: The Defense Meteorological Satellite Program (DMSP) enhancement, to be deployed at the Thule Tracking Station (TTS), comprises a group of special-purpose equipment which links the DMSP Satellite Operations Center (SOC), via a DOMSAT link, to the ARTS Core or to TTS. The DMSP enhancement proposed by Ford Aerospace is designed to provide ARTS interoperability as a DMSP Command Readout Station (CRS) or with a DMSP Local Command Processor (LCP). The design provides a transparent interface with the DMSP spacecraft for either the SOC or the LCP.

The ARTS contract provides an option to accommodate the potential move of a DMSP LCP from Loring, Maine to Thule. After the ARTS with the DMSP enhancements checks out as a CRS to either Offut or Loring then Loring may be dismantled and moved to TTS. ARTS would then be capable of remote operation with DMSP control or a semi-independent operation with a colocated command processor.
(Viewgraph #13, ADMF)

d) **ADMF Enhancement**: The ADMF will include an exact duplicate of the ARTS Core. The ARTS C&S software will be designed using an Ada Program Development Language (PDL). Ford Aerospace developed Ada syntax checking software will validate the Ada PDL. The implementation from the Ada PDL will be in JOVIAL J-73, compatible with the DSM program. The JOVIAL code will be compiled and tested on IBM mainframes, such as the 4341, prior to being cross-compiled into Intel assembly code. Better than 60% of C&S code will be in JOVIAL, while the remainder will be in Intel assembly language.
(Viewgraph #14, MMI Interface)

e) **Operations and Maintenance**: ARTS may be operated from a single console with a recommended staffing of two persons: an operator, and a tape handler/maintainer. A simulation of the MMI interface during the proposal phase showed that menu-driven, color coded displays, coupled with an LRU off-site repair approach provides effective operations support. System displays are selected by cursor or keyboard input from a hierarchy of related displays. Fault alarms override the top level system monitoring displays and the menu depicts operator choices for focusing the alarm source. Multiple or sequential alarm data are stored for future operator access.

Systems reliability and maintainability are closely linked to a system's LCC. Reliability parameters serve to determine the frequency of maintenance operations which, in turn, affect maintenance costs. Reliability is also a major factor in defining the ARTS spares requirements. Our LCC/AMA modeling efforts have led us to an ARTS design that exceeds specified RMA requirements. The design meets these requirements without redundancy by using a unique concept of equipment pooling. A summary of the RMA achieved by our ARTS design is:

RMA REQUIREMENTS	SPECIFIED REQUIREMENTS	ACHIEVED REQUIREMENTS
Mean Time Between Failures	150 Hours	174 Hours
Mean Time to Restore	0.5 Hours	0.488 Hours
Maximum Downtime	2.0 Hours	1.0 Hours
Preventive Maintenance Time Per Week	2.0 Hours	1.62 Hours
Availability	0.997	0.9971

f) **Automated Test**. The Ford Aerospace design provides complete site readiness tests, not just selected continuity checks, in only 296 seconds (worst case) of station time for the RCC/NCS and for the MCC. This is achieved by executing multiple concurrent telemetry and tracking tests and by using a "partial response, forced bit error" measurement technique to check downlink performance at very low data rates. We have developed equally comprehensive approaches for performance, diagnostic, and calibration testing.

Automated Testing Man-Machine Interface. The ARTS automatic testing is easily initiated, controlled, and monitored from the C&S computer terminal at the station control console. A menu of readiness tests tailored for a particular IRON can be displayed by pressing the keyboard function key labeled READY TEST. The performance, calibration, and fault isolation tests are also available from menus for the individual subsystem and equipment detail displays.

Ford Aerospace's MMI for automated testing is integrated into the overall display hierarchy which depicts the status of the systems and subsystems. This approach gives the operator a logical and consistent frame of reference. When a problem is identified, from either the readiness or the automatic selfchecking tests, the technician/operator can easily find the lowest level required and then select the appropriate tests to isolate the current problem.

Readiness Tests. Readiness testing may be conducted from the RCC (or NCS) and MCC, but can also be initiated at the ARTS control console. These Go/No Go tests are completely automated. Uplink command bit error rate (BER) and output power tests occur first, followed by all others in parallel. A full readiness test conducted by the RCC/NCS and repeated by the MCC can always be completed in under 5 minutes. The worst case (maximum time required) includes the processing of five telemetry PCM bit streams at low bit rates (all less than 25 kb/s) as well as the long code for ranging.
(Viewgraph #15, Complete site Readiness Test Meets Turnaround Requirements)

Upon completion of the individual readiness tests, a summary of the results is generated, displayed at the ARTS control console, and transmitted to the STC or CSOC. This occurs at some time that voices between 1:45 and 2:25 (min:sec) after initiation of the test by the RCC.

Both the RCC and the MCC are free to accelerate their respective ARTS readiness sequences by deleting tests and/or substituting continuity checks for BER tests. Since the Ford Aerospace ARTS design achieves a 5-minute turnaround without compromise, such measures would only be necessitated in the event of two very closely spaced high-priority passes.

Performance Tests. Whether initiated from the ARTS control console, STC, or CSOC, performance tests are conducted to determine quantitative station performance. These tests, which examine the entire equipment operating range, verify performance on a routine basis or reverify equipment capabilities after the site technician replaces failed units and performs calibrations. Actual performance figures generated during these tests are available on hardcopy. The seven required performance tests are provided by ARTS.
(Viewgraph #16, Complete Performance Tests are Provided)

<u>Fault Isolation and Detection</u>. Fault isolation and detection is performed from the ARTS control console for corrective and scheduled maintenance. Signal injection capabilities, test points, status data monitoring, built-in test features, and system operational switching permit fault isolation to the assembly or subassembly level.

Ford Aerospace design provides sequenced loop testing so that units more likely to fail are checked first. This approach not only minimizes the time required to isolate faults when they occur, but also provides the best chance to support the upcoming vehicle contact by replacing the failed unit in a pool with a good one. Few contacts actually require all the units contained in a pool.

<u>Calibration Tests</u>. Calibration tests establish or reestablish system acceptance limits and aid in checking overall system performance. Calibration tests automated in ARTS include:

a. Solar Y factor G/T

b. Automatic Gain Calibration

c. Modulation Index

d. Range Bias Error

e. Azimuth and Elevation Bias Error

f. Noise Figure

g. Signal-to-Noise vs. Bit Error Performance

(Viewgraph #17, Systems Growth)

g) **<u>Growth Potential</u>**. The ARTS system was required to be compatible with future systems additions in three areas: Ku-band, Adaptive Side Lobe Cancellation (ASLC), and possible future network additions. The first requirement is met by a reflector with the tolerance to support Kuband. Four horns would be added to the reflector to facilitate the ASLC addition. The third will be met using a memory mapping technique which would accommodate a new bent-pipe or new local commanding interface by inserting a table that will link that network with ART'S TT&C and C&S facilities.

5. CURRENT STATUS

Subcontractor Negotiations: The total ARTS team is under contract and proceeding to develop material for the Preliminary Design Review (PDR). Technical personnel of each team member report to the Ford Aerospace Lead Systems Engineer (LSE) as if they were an internal work order recipient. A separate manager in the PMO tracks performance against contract while the LSE tracks performance against program milestones. A separate QA function monitors both hardware and software quality. Detailed specifications negotiated after the proposal but prior to award (and refined after award) led to a detailed milestone list which is tending to focus attention on problem areas.

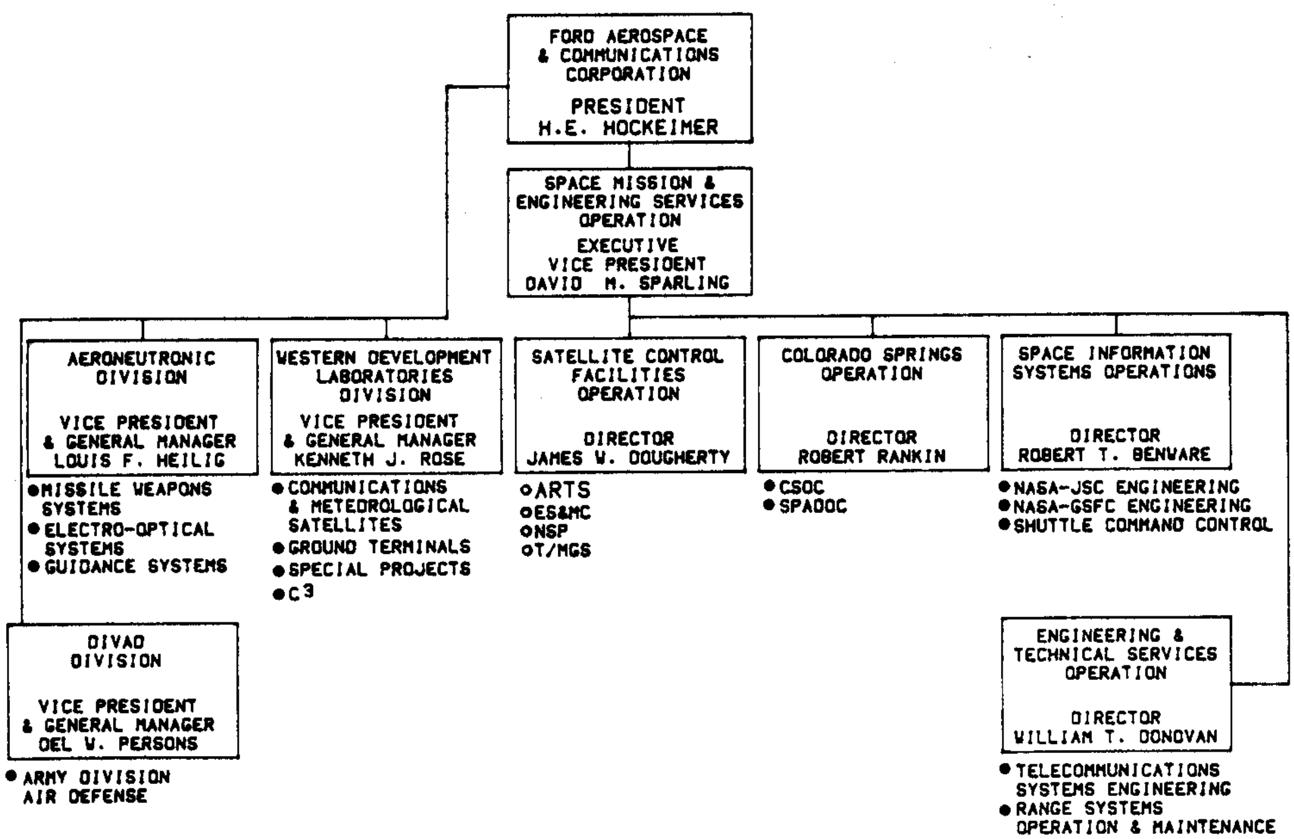
System Design Review: The SDR is scheduled for early September, 1984. A report on content and perceived reaction to that content will be given at the ITC conference.

Program Schedule: The ARTS program was put into PERT chart form during the proposal effort. An updated bar chart derivative of that PERT will be shown at the conference.

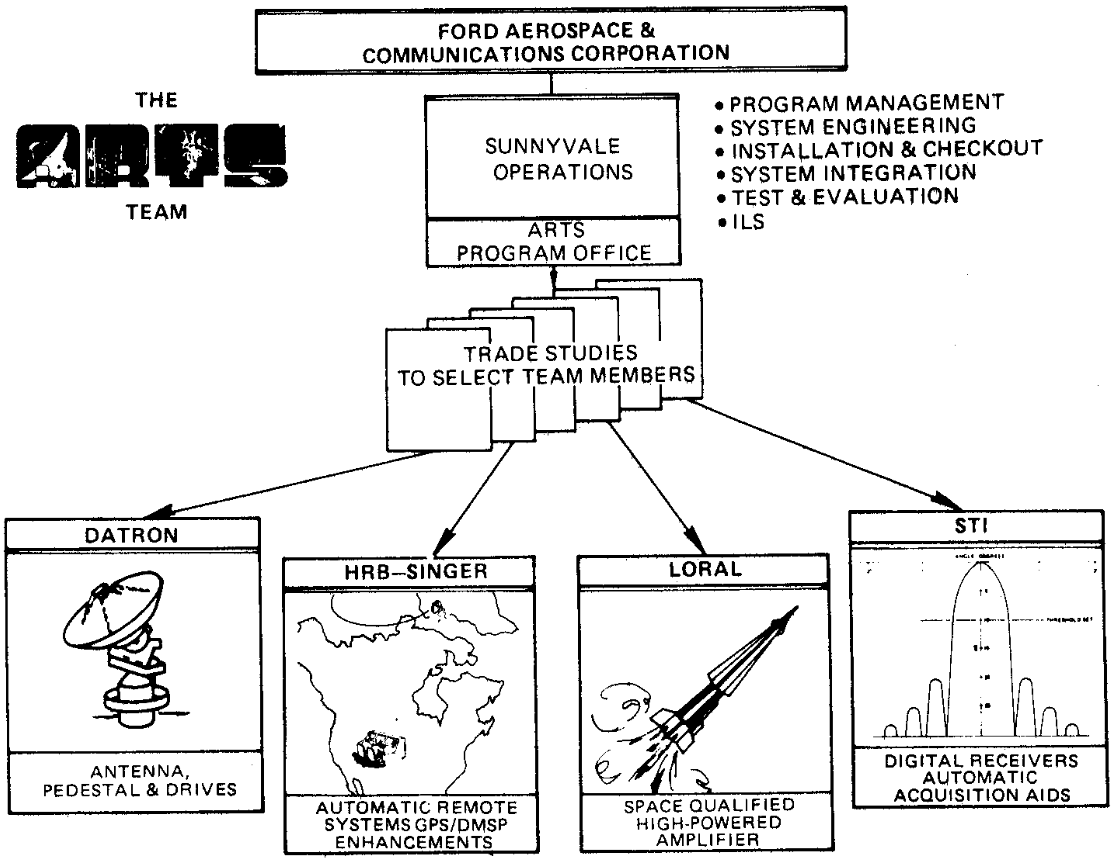
AUTOMATED REMOTE TRACKING STATION

Ford Aerospace & Communications Corporation

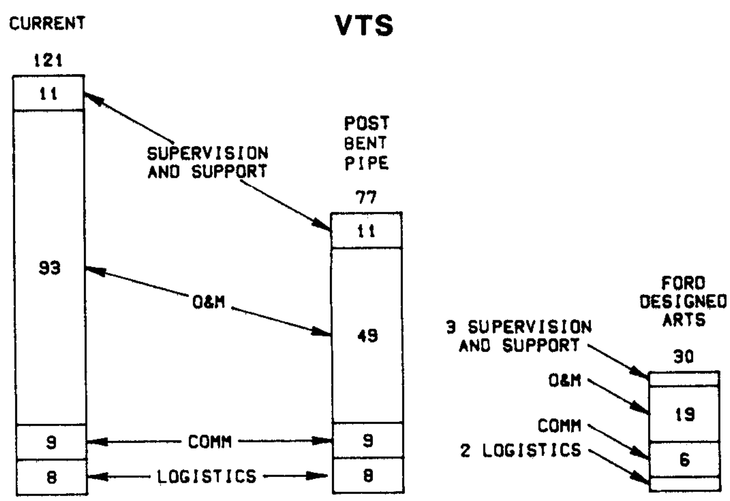
THE ARTS PROGRAM HAS EXECUTIVE VISIBILITY WITHIN FORD AEROSPACE



THE ARTS TEAM



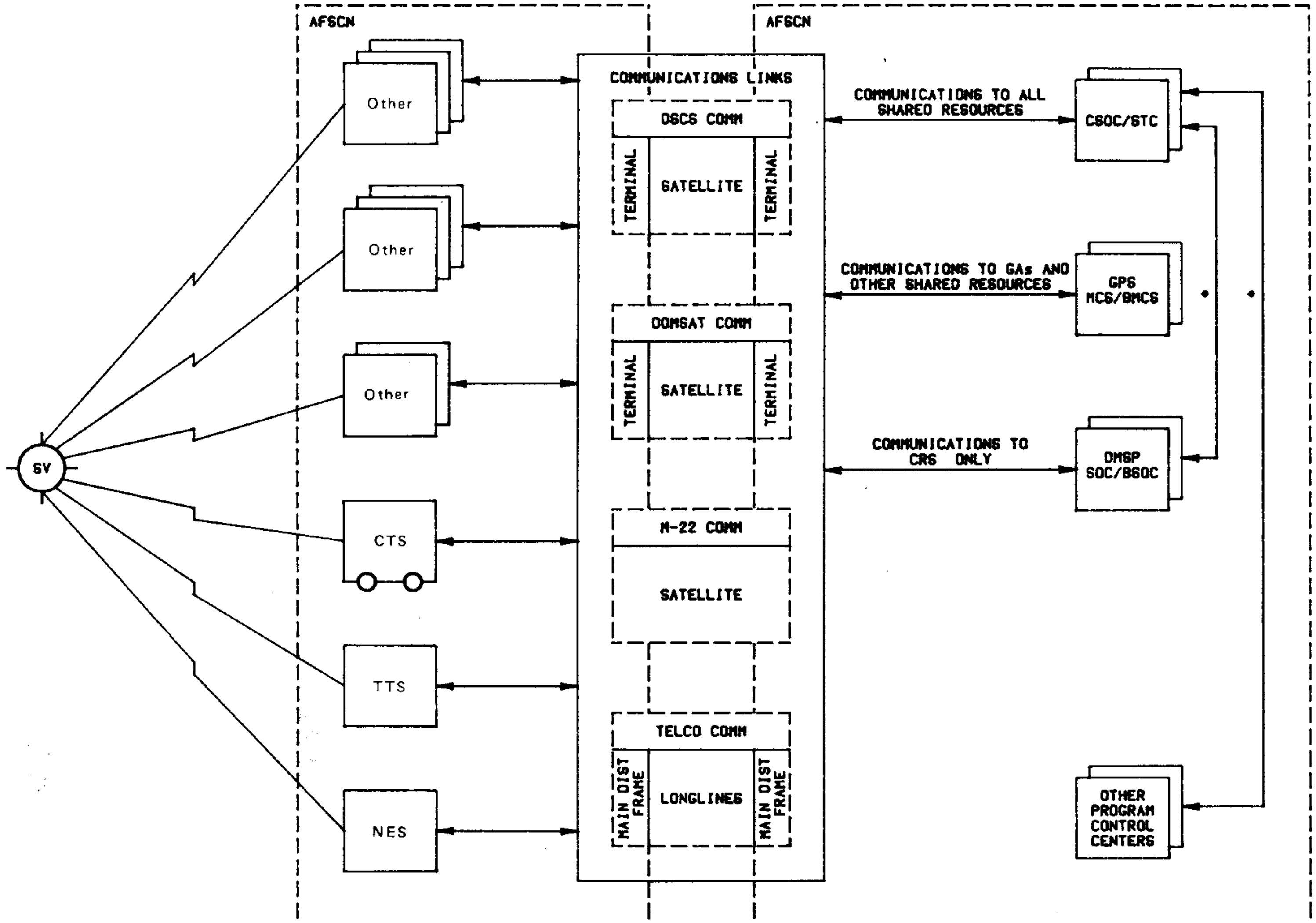
THE FORD AEROSPACE MANNING CONCEPT FOR THE ARTS COULD PROVIDE DRAMATIC, NETWORK-WIDE COST REDUCTIONS FOR THE AFSCN



READINESS TEST TIMES

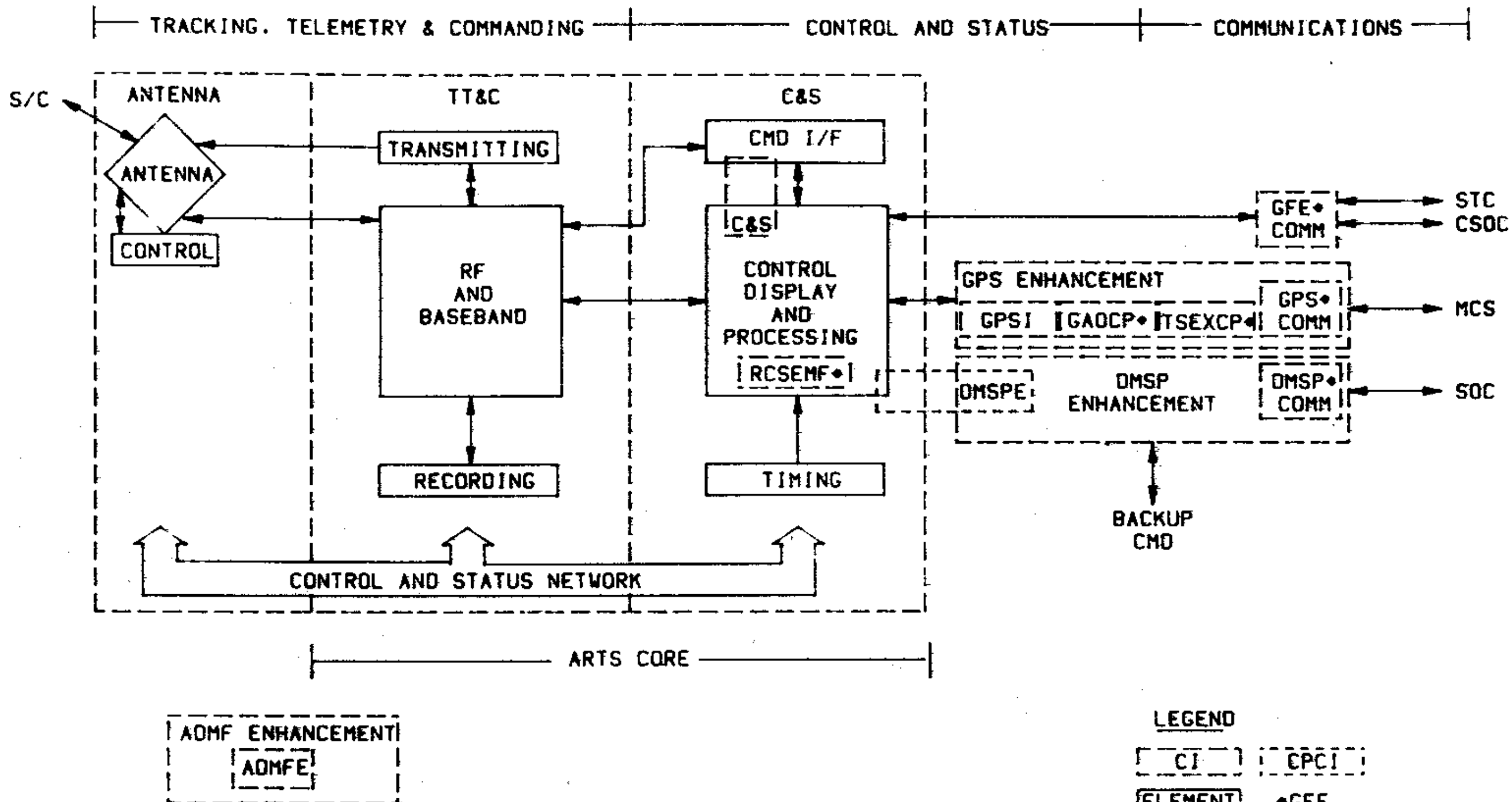
TEST	RCC/NCS TIME –SECS (BER TESTING)								MCC TIME–SECS (CONTINUITY TESTING)							
CONFIG. STATION	10								10							
CONFIG. TEST LOOP	5								5							
UPLINK CMD. TEST	10								5							
CONFIG. TEST LOOP	5								5							
TLM TEST (WORST)		108								36						
RANGE TEST (LONG CODE)			86								67					
TLM TEST (AVERAGE)				70								36				
RECORDER TEST					70								10			
M34 TEST						63								10		
TLM TEST (BEST)							56								36	
RANGE TEST (SHORT CODE)								36								20
COLLECT STATUS DATA	5								5							
GENERATE STATUS REPORT	5								5							
TOTAL RCC/NCS TIME		148	126	110	110	103	96	76		71	102	71	45	45	71	55
TOTAL RCC/NCS & MCC TIME		296	252	220	220	206	192	152		219	228	181	155	148	167	131

ARTS PHASE I OF AFSCN

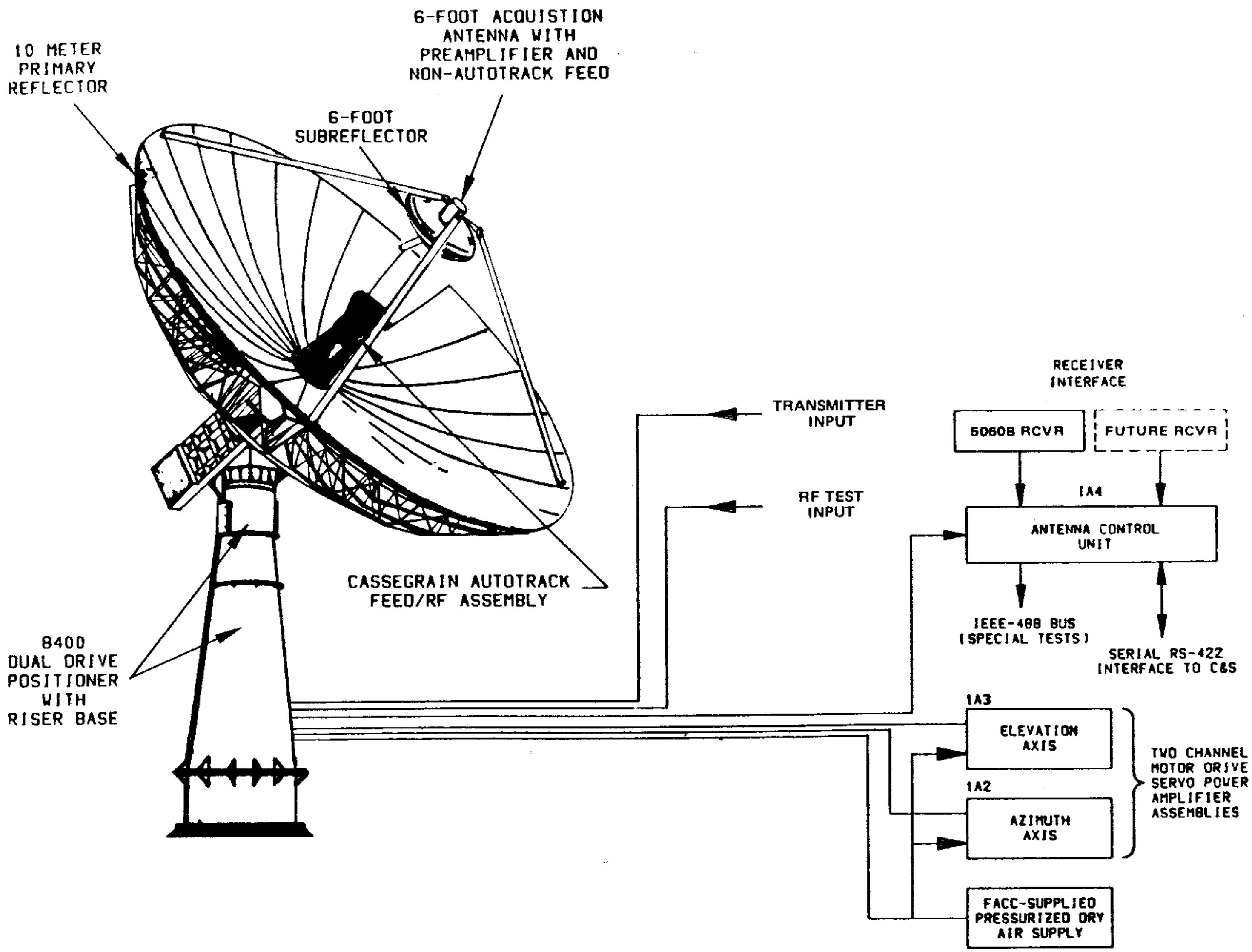


* COMMUNICATIONS FROM THESE CONTROL CENTERS TO THE SHARED RESOURCES WILL BE VIA THE COMMUNICATIONS SEGMENT AT CSOC OR STC.

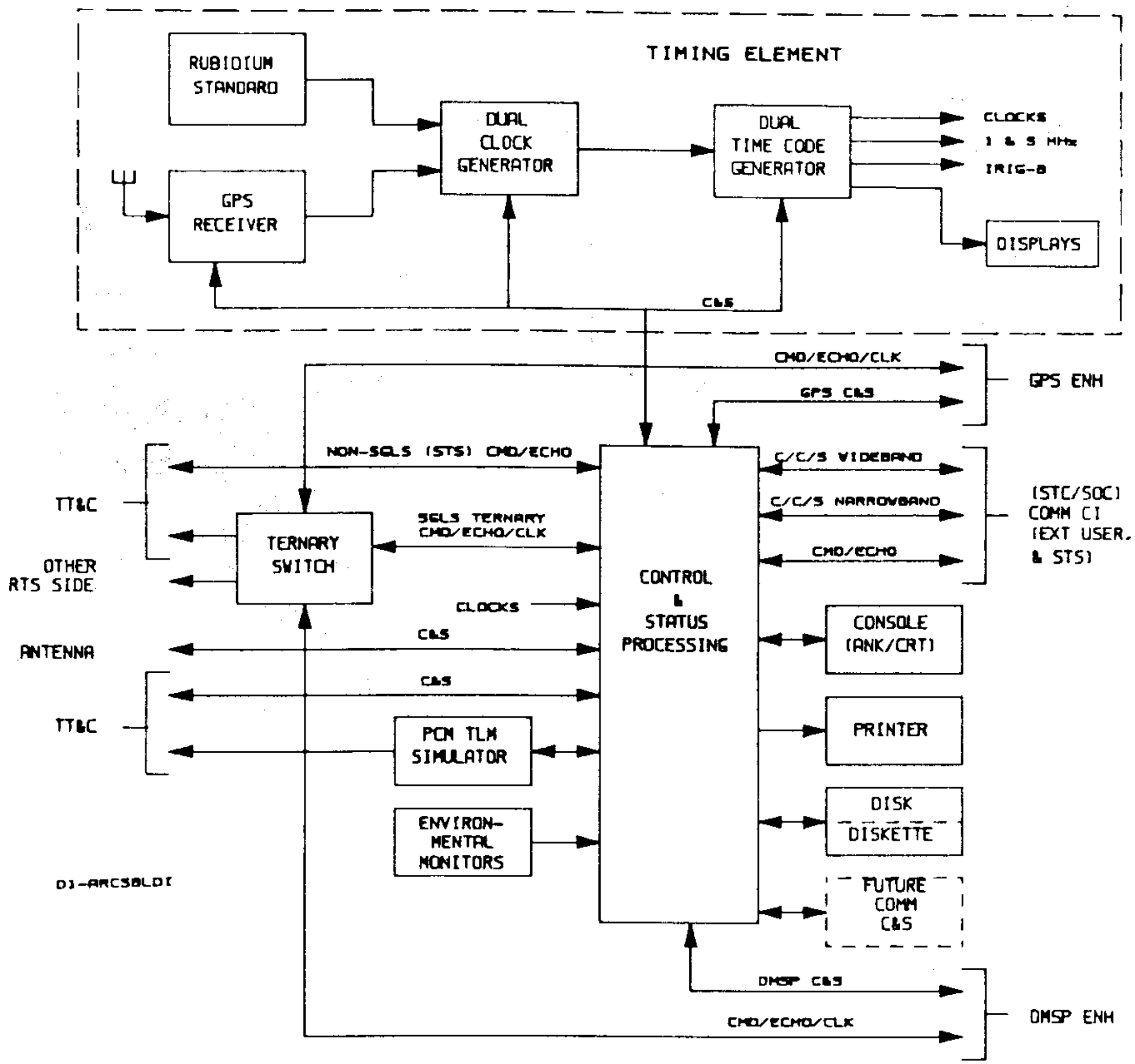
SYSTEM SCHEMATIC



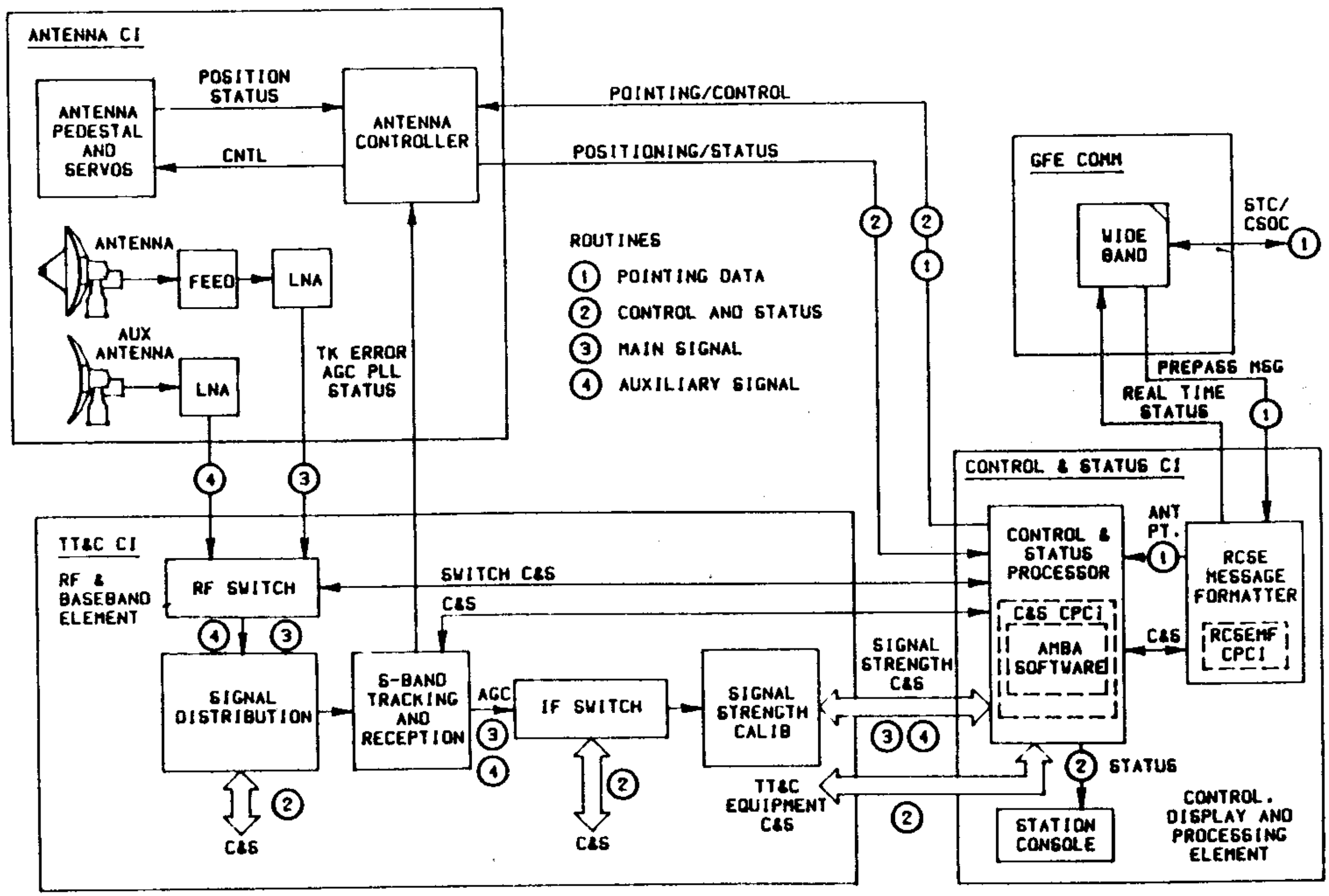
THE ARTS ANTENNA



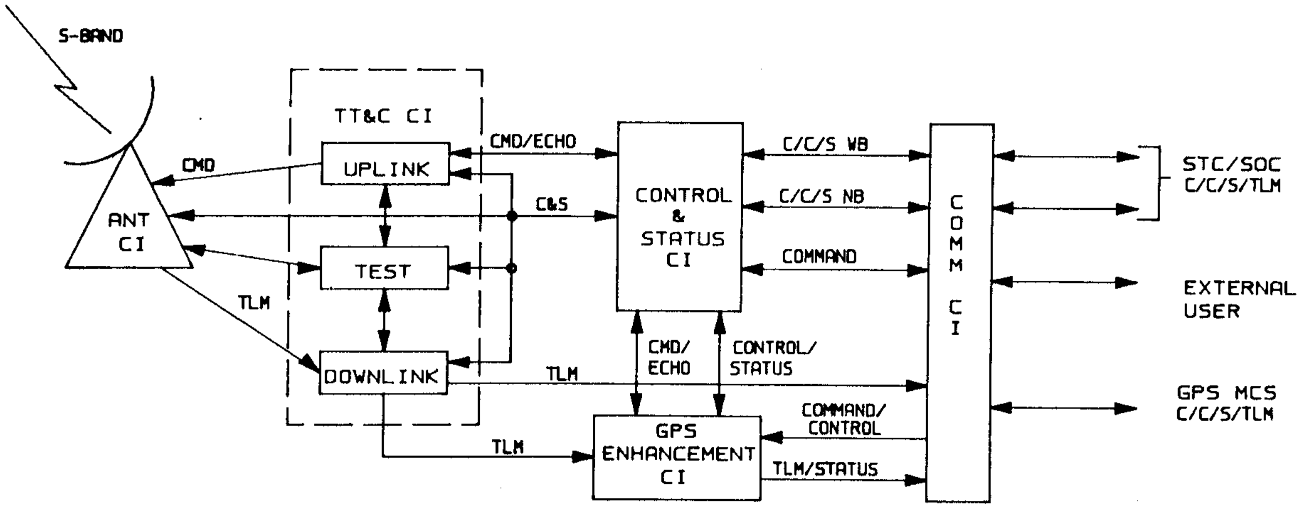
ARTS CONTROL & STATUS CI BLOCK DIAGRAM



MAIN BEAM ACQUISITION

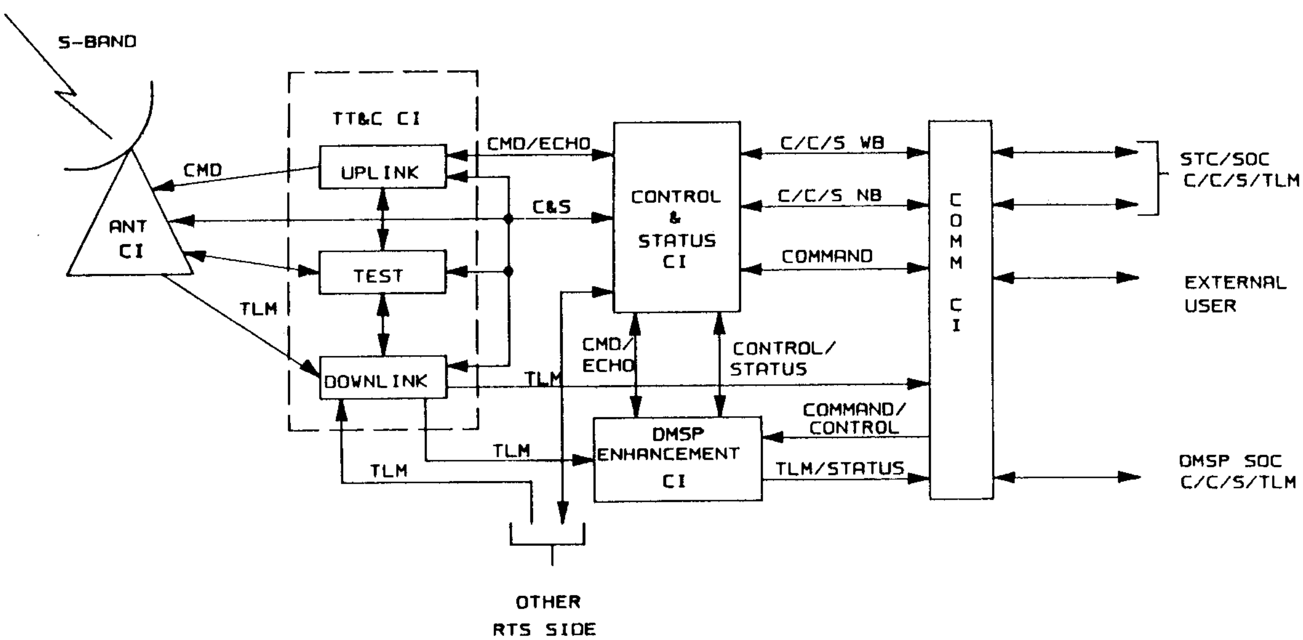


GPS ENHANCED ARTS SYSTEM DESIGN SUMMARY



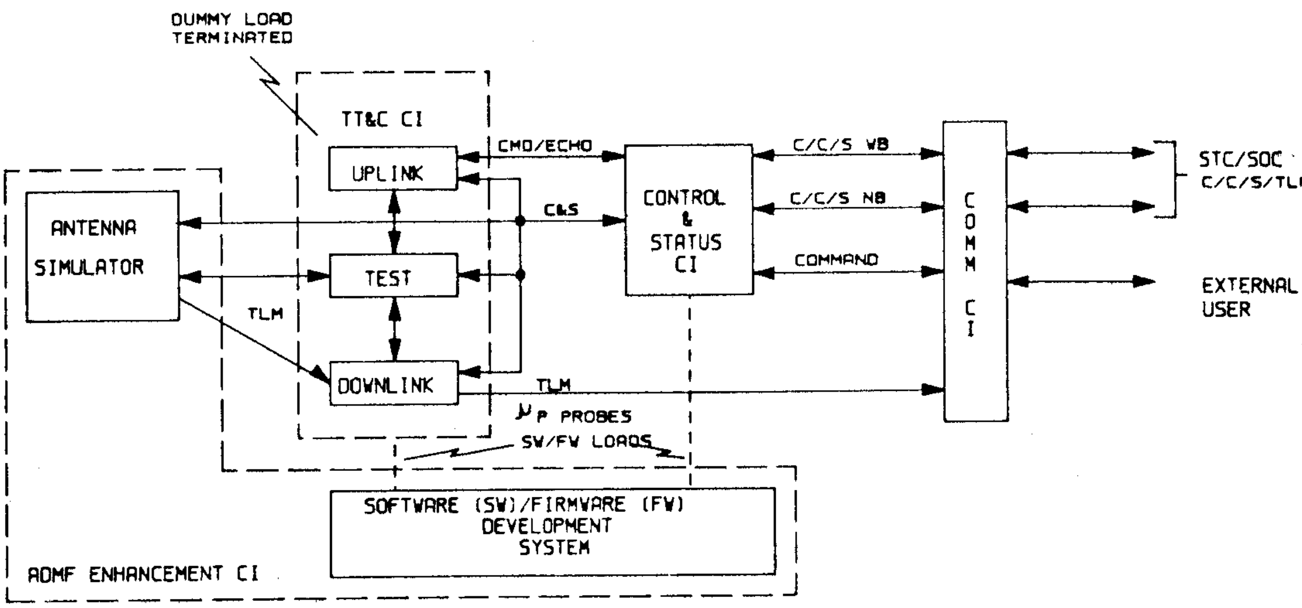
D1-ARGPENSY

DMSP ENHANCED ARTS SYSTEM DESIGN SUMMARY



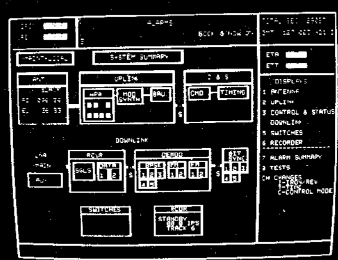
D1-ARDMENSY

ADMF ENHANCED ARTS SYSTEM DESIGN SUMMARY

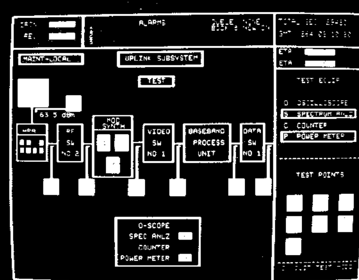


D1-ARADMFSY

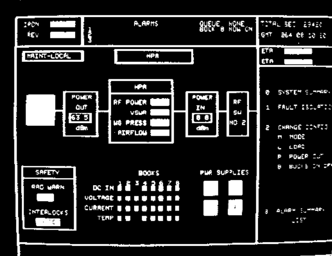
SYNERGISTIC MAN–MACHINE INTERFACE



- HIERARCHICAL CONTROL, STATUS, FAULT ISOLATION & DIAGNOSTICS – – SYSTEM TO SUBSYSTEM TO EQUIPMENT LEVEL



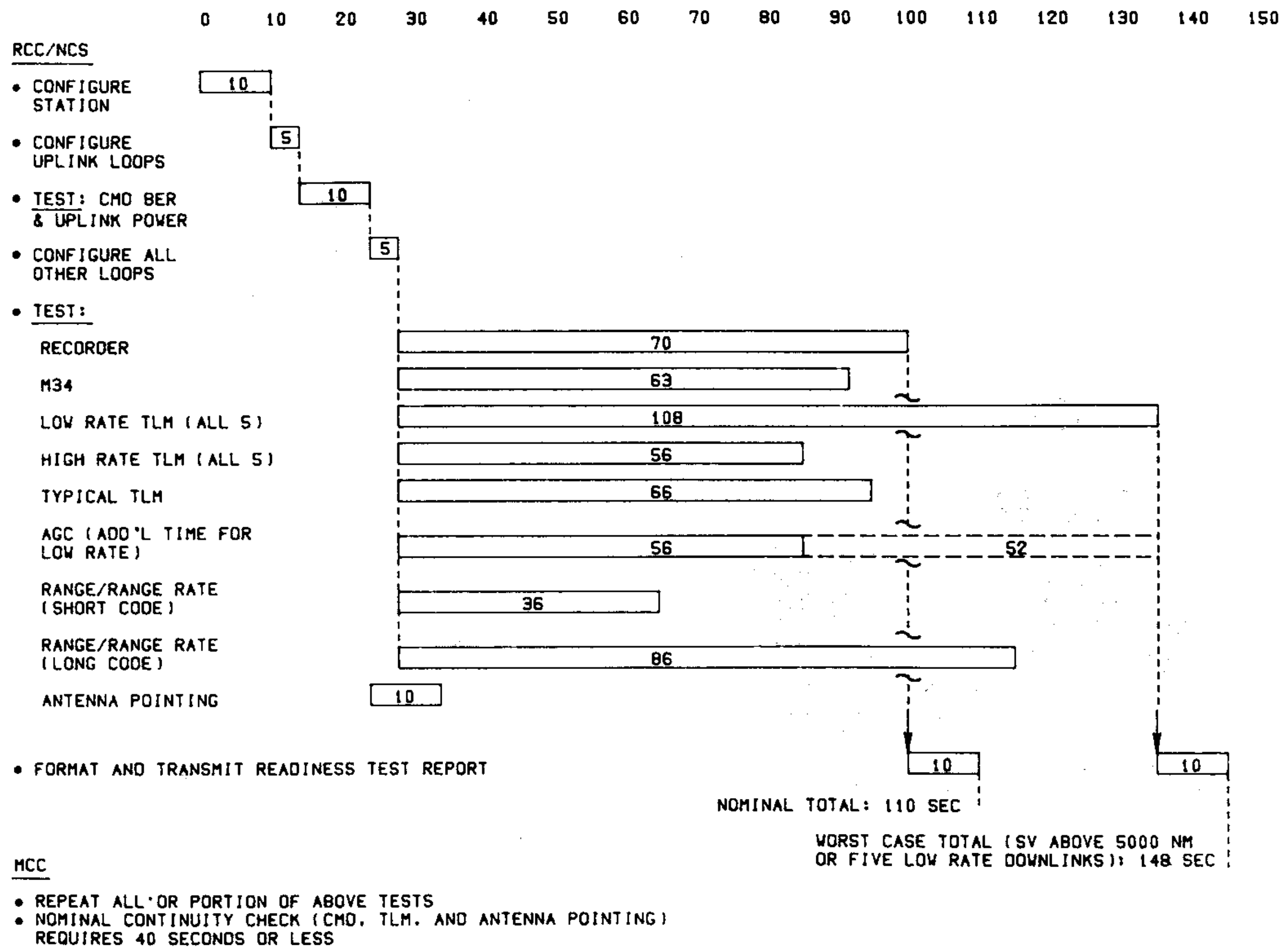
- CURSOR OR COMMAND DRIVEN – – ACCOMMODATES ANY LEVEL OF USER EXPERIENCE



- EASY TO COMPREHEND COLOR SCHEME – –

  GREEN: ON – LINE/OPERATIONAL
  WHITE: OFF – LINE/AVAILABLE STANDBY
  RED: FAULT DETECTION
  BLUE: TEST CONFIGURATION

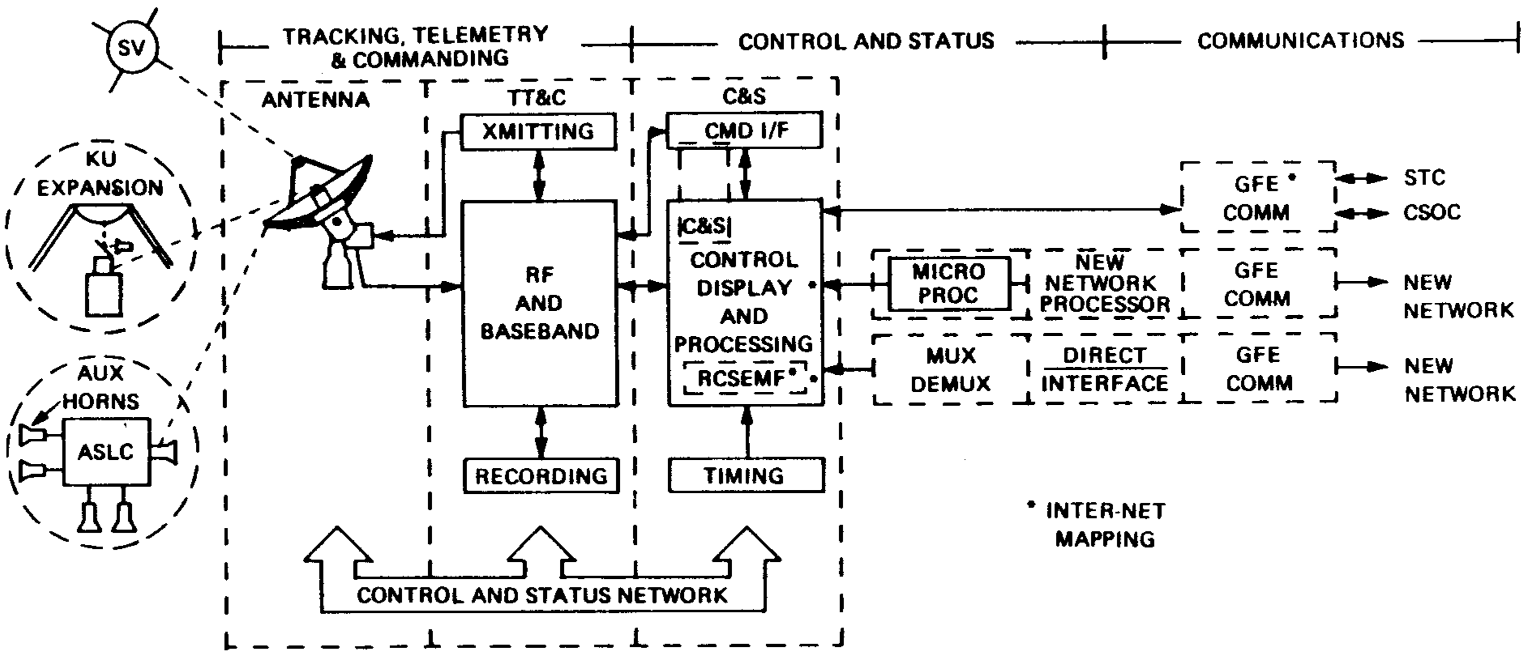
COMPLETE SITE READINESS TEST MEETS TURNAROUND REQUIREMENTS



COMPLETE PERFORMANCE TESTS ARE PROVIDED

TEST	COMPARISON TO READINESS TEST	REMARKS
COMMAND UPLINK BER	SIMILAR TO READINESS TEST	BER TEST USED AS DATA SOURCE AND ERROR DETECTOR. TEST PERFORMED OVER OPERATING RANGE: MODULATION INDICES, COMMAND RATES, FREQUENCY RANGE AND POWER RANGE.
TELEMETRY DOWNLINK BER	SIMILAR TO READINESS TEST	TEST PERFORMED OVER OPERATING RANGE: PCM CODES, PCM BIT RATES, SIGNAL-TO-NOISE CHARACTERISTICS. PERMITS EVALUATION OF E_b/N_o CHARACTERISTICS.
RANGE ERROR/RANGE RATE	SIMILAR TO READINESS TEST	TEST PERFORMED OVER OPERATING RANGE: LONG AND SHORT CODES, MODULATION INDICES, SIGNAL-TO-NOISE CHARACTERISTICS, SIMULATED FULL RANGE DELAY, AND DOPPLER SHIFT RANGE.
TIMING EQUIPMENT	-	COMPARES ARTS FREQUENCY STANDARDS WITH KNOWN CALIBRATION DATA.
TRACKING DATA	-	USES KNOWN SATELLITE REFERENCE DATA TO VERIFY SYSTEM PERFORMANCE (TRACKING AND POINTING DATA WITHIN ACCEPTABLE LIMITS).
TRANSMITTER	SIMILAR TO READINESS TEST	TEST PERFORMED OVER OPERATING RANGE: POWER INTO DUMMY LOAD, FORWARD AND REFLECTED POWER INTO ANTENNA, VSWR, GAIN VS BANDWIDTH (OVER POWER RANGE).
RECORDING MEDIA	SIMILAR TO READINESS TEST	TEST PERFORMED FOR RANGE OF DATA RATES.

SYSTEMS GROWTH POSSIBILITIES FOR ARTS



ADDING KU BAND – ADDING ASLC CAPABILITY – ADDING NEW NETWORKS