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COMMUNICATIONS AND TRACKING

DISTRIBUTED SYSTEMS EVOLUTION STUDY

ABSTRACT

THE COMMUNICATIONS AND TRACKING (C & T) TECHNIQUES AND EQUIPMENT TO SUPPORT EVOLUTIONARY SPACE STATION CONCEPTS ARE BEING ANALYZED. EVOLUTIONARY SPACE STATION CONFIGURATIONS AND OPERATIONAL CONCEPTS WERE USED TO DERIVE THE RESULTS TO DATE. A DESCRIPTION OF THE C & T SYSTEM BASED ON FUTURE CAPABILITY NEEDS IS PRESENTED. INCLUDED ARE THE HOOKS AND SCARS CURRENTLY IDENTIFIED TO SUPPORT FUTURE GROWTH.

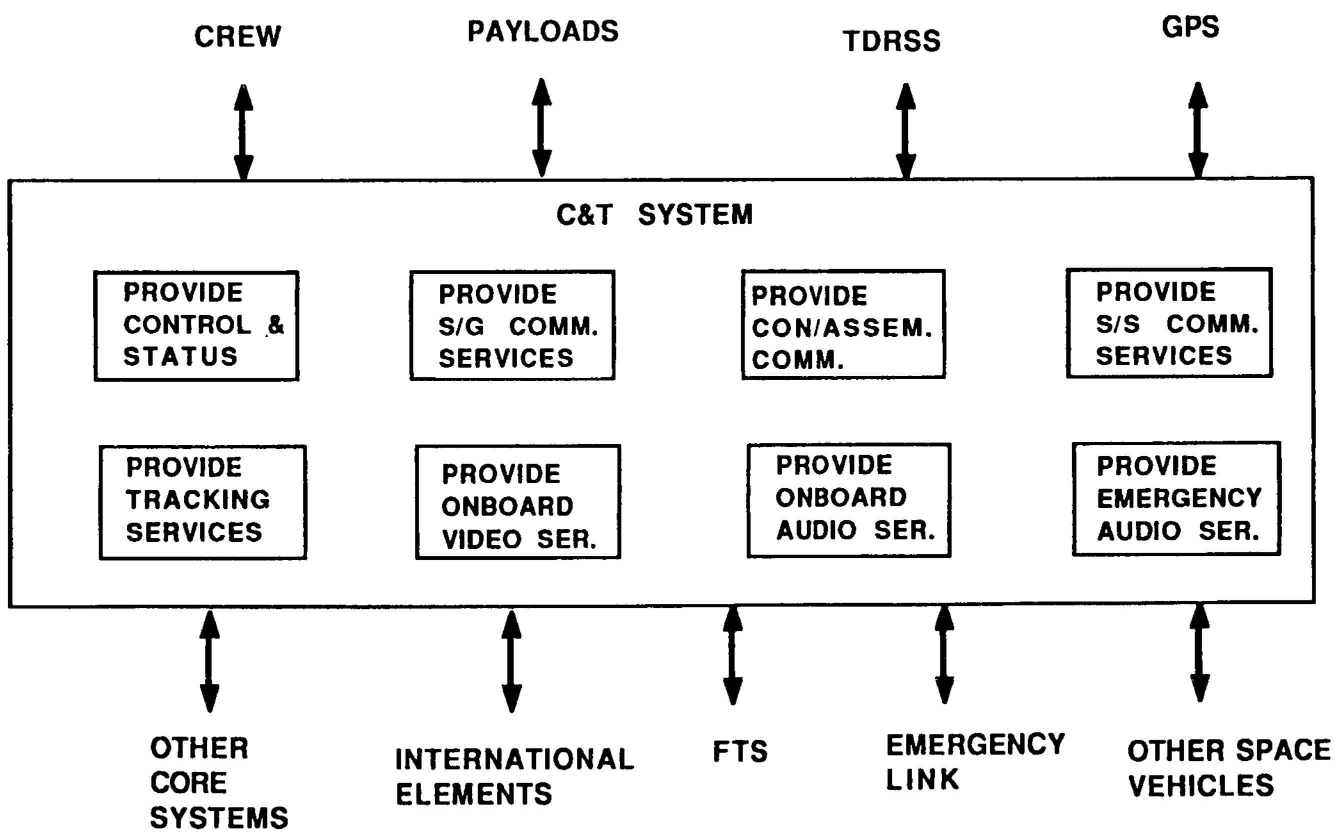
INTRODUCTION

JSC TRACKING AND COMMUNICATIONS DIVISION (TCD) HAS BEEN TASKED TO EXAMINE THE EVOLUTION COMMUNICATION AND TRACKING REQUIREMENTS FOR SPACE STATION FREEDOM (SSF). THE STUDY IS STRUCTURED TO BEGIN THE ANALYSIS BY PAIRING THE INITIAL OPERATIONAL CAPABILITY OF SSF C&T SYSTEM AND ITS MERITS AGAINST KNOWN OPERATIONAL REQUIREMENTS. THE EVOLUTION C&T FUTURE NEED REQUIREMENTS ARE THEN IDENTIFIED. ULTIMATELY, THE STUDY CONCLUDES WITH RECOMMENDATIONS FOR MODIFICATION TO THE SSF C&T SYSTEM AND THE REQUIRED HOOKS AND SCARS TO ENSURE AN UNIMPEDED EVOLUTION PROCESS.

Text for C&T Functional Diagram

The Space Station Freedom C&T system consists of centralized and distributed redundant components that provide for:

1. Space-to-ground communications services.
   Transmission, reception and signal processing of audio, video, telemetry, command, data, text, and graphics between the SS freedom and TDRSS ground station.
2. Space-to-space communications services.
   Transmission, reception and signal processing of audio, video, telemetry, command, data, text and graphics between the SS freedom and space interoperating elements including FTS, EVAs, international elements, etc.
3. Space-to-ground assembly/contingency communications services.
   Transmission, reception and signal processing of audio, telemetry, and command between the SS Freedom and ground station during assembly and contingency phases.
4. Tracking services.
   Delivery of tracking and area-traffic control information and reference time signals to other Space Station systems.
5. Control and monitoring services.
   Monitoring the functioning of the C&T system and reporting status, performance and configuration data.
6. Onboard audio services.
   Processing and distribution of audio signals within the Space Station.
7. Onboard video services.
   Processing and distribution of video signals within the Space Station.


CREW
PAYLOADS
TDRSS
GPS
C&T SYSTEM
PROVIDE CONTROL & STATUS
PROVIDE S/G COMM. SERVICES
PROVIDE CON/ASSEM. COMM.
PROVIDE S/S COMM. SERVICES
PROVIDE TRACKING SERVICES
PROVIDE ONBOARD VIDEO SER.
PROVIDE ONBOARD AUDIO SER.
PROVIDE EMERGENCY AUDIO SER.
OTHER CORE SYSTEMS
INTERNATIONAL ELEMENTS
FTS
EMERGENCY LINK
OTHER SPACE VEHICLES

Text for Future Capability Needs

The operation of SS Freedom in the evolutionary time frame has several tasks to upgrade communications system to support new requirements with new technology insertion including (a) accommodation of high data rate payloads, and scientific experiments, (b) interface with Advanced Tracking and Data Satellite System (ATDRSS) (which can provide up to 650 Mbps space-to-ground data transmission capability), and (c) support of larger numbers of space-to-space interoperating elements or users including those inter-planetary (Mars and Moon) exploration vehicles at extended communication distance.

The tracking tasks can be broadly lumped into four categories including (a) rendezvous and docking/berthing monitoring and control, (b) proximity operations monitoring and control, (c) orbital debris monitoring, and (d) crew and equipment retrieval support. Items (b) and (d) can be lumped together into one class. Requirements definition for these tracking operations is difficult and complex. Our study is examining requirements definition, but also performing analysis to portray differing sensor performance within scenario classes.

Examination of the issues for future capability needs allows identification of hooks and scars, the most important of which are discussed further in this presentation.

COMMUNICATIONS:

IDENTIFY MISSION AND TECHNOLOGY DRIVERS AND DEFINE HOOKS AND SCARS REQUIRED FOR THE COMMUNICATIONS SYSTEM(S) TO SUPPORT REQUIREMENTS AND NEW TECHNOLOGY INSERTION INCLUDING:

- ACCOMMODATION OF HIGH DEFINITION TV
- ACCOMMODATION OF HIGH DATA RATE PAYLOAD AND EXPERIMENTS.
- INTERFACE WITH THE ADVANCED TRACKING AND DATA SATELLITE (ATDRSS)
- SUPPORT OF LARGER NUMBERS OF SPACE-TO-SPACE LINK USERS AND EXTENDED COMMUNICATIONS DISTANCES FOR NSTS AND OTHERS LIKE MOON AND MARS.

TRACKING:

IDENTIFY DRIVERS, HOOKS AND SCARS REQUIRED FOR SYSTEMS TO SATISFY THE FUTURE NEEDS AND NEW TECHNOLOGY FOR :

- RENDEZVOUS AND DOCKING MONITORING AND CONTROL
- ROBOTIC AND OTHER PROXIMITY OPERATIONS MONITORING AND CONTROL.
- ORBITAL DEBRIS MONITORING .
- CREW AND EQUIPMENT RETRIEVAL SUPPORT

Text for WP-2 Evolutionary Growth Plan

The current MDAC WP-2 Evolution Growth Plan for the communications system calls for adding the S-band feed to the Space-to-ground TDRSS parabolic antenna to support the S-band link for providing contingency when the normal space-to-ground Ku-band link fails or is for any reason unable to provide communications function.

The current growth plan also provides video support for the serving facility and additional payloads up to a maximum of 18. The NTSC video signal will be distributed in the red, green, and blue (RGB) components instead of composite form to improve the picture quality.

For the Space-to-Space communications services, the current growth plan calls for (a) addition of one omni antenna for the servicing facility, (b) implementation of switch matrices to support up to 16 antenna mounted equipment (AME) and 8 transceiver/modems in each node, (c) additions of transceiver/modems in each node to support more interoperating elements, and (d) additions of baseband signal processing (BSP) equipments to fully support additional transceiver/modems in each node except that no more than 2 video forward channels and 8 video return channels need be supported.

SPACE-TO-GROUND SUBSYSTEM

- USE OF THE S-BAND FEED IN THE TDRSS PARABOLIC ANTENNA

VIDEO SUBSYSTEM

- PROVIDE SUPPORT FOR THE SERVICING FACILITY AND ADDITIONAL PAYLOADS UP TO A MAXIMUM OF 18.
- PROVIDE PROVISIONS TO DISTRIBUTE RED, GREEN AND BLUE (RGB) COMPONENT VIDEO SIGNALS

SPACE-TO-SPACE SUBSYSTEM

- ONE ADDITIONAL OMNI ANTENNA FOR THE SERVICING FACILITY
- SWITCH MATRICES TO INDIVIDUALLY SUPPORT UP TO 16 ANTENNA/AME EQUIPMENT AND EIGHT TRANSCEIVER/MODEMS IN EACH NODE
- ADDITIONAL TRANSCEIVER/MODEMS IN EACH NODE
- BSP EQUIPMENT TO FULLY SUPPORT ADDITIONAL TRANSCEIVER/MODEMS IN EACH NODE EXCEPT THAT NO MORE THAN TWO VIDEO FORWARD CHANNELS AND EIGHT VIDEO RETURN CHANNELS NEED BE SUPPORTED

Text for WP-2 Evolutionary Growth Plan (Continued)

The MDAC Wp-2 Evolution Plan calls for additional local controllers, bus couplers, buses, dedicated mass storage units, network couplers, processors for the Control and Monitor subsystem to accommodate anticipated growth demand for supporting more complicated communications and tracking tasks. Also, knowledge based expert system with necessary software will be installed to assist and expedite executions of various C&M tasks.

The MDAC Wp-2 Evolution Plan also calls for the addition of a Laser Docking Sensor, and a tracking support RADAR for the Tracking Subsystem. The evolution study supports these recommendations, but concludes that the infrastructure to effectively use those tools is missing for the Space Station. A device to coordinate data from various tracking inputs is necessary. A Tracking Processor is proposed to meet that need.

MDAC WP-2 EVOLUTIONARY GROWTH PLAN (CONTINUED)

CONTROL AND MONITOR SUBSYSTEM

- EXPERT SYSTEM SOFTWARE
- EXPERT SYSTEM DECISION EXPLANATION FACILITY
- ADDITIONAL C&M PROCESSORS
- ADDITIONAL C&M NETWORK COUPLERS (I.E. RING CONCENTRATORS)
- ADDITIONAL LOCAL CONTROLLERS
- DEDICATED MASS STORAGE UNITS
- ADDITIONAL LOCAL BUS COUPLERS
- ADDITIONAL LOCAL BUSES

TRACKING SYSTEM

- RADAR FOR DOCKING AND BERTHING
- LASER RANGING FOR DOCKING AND BERTHING

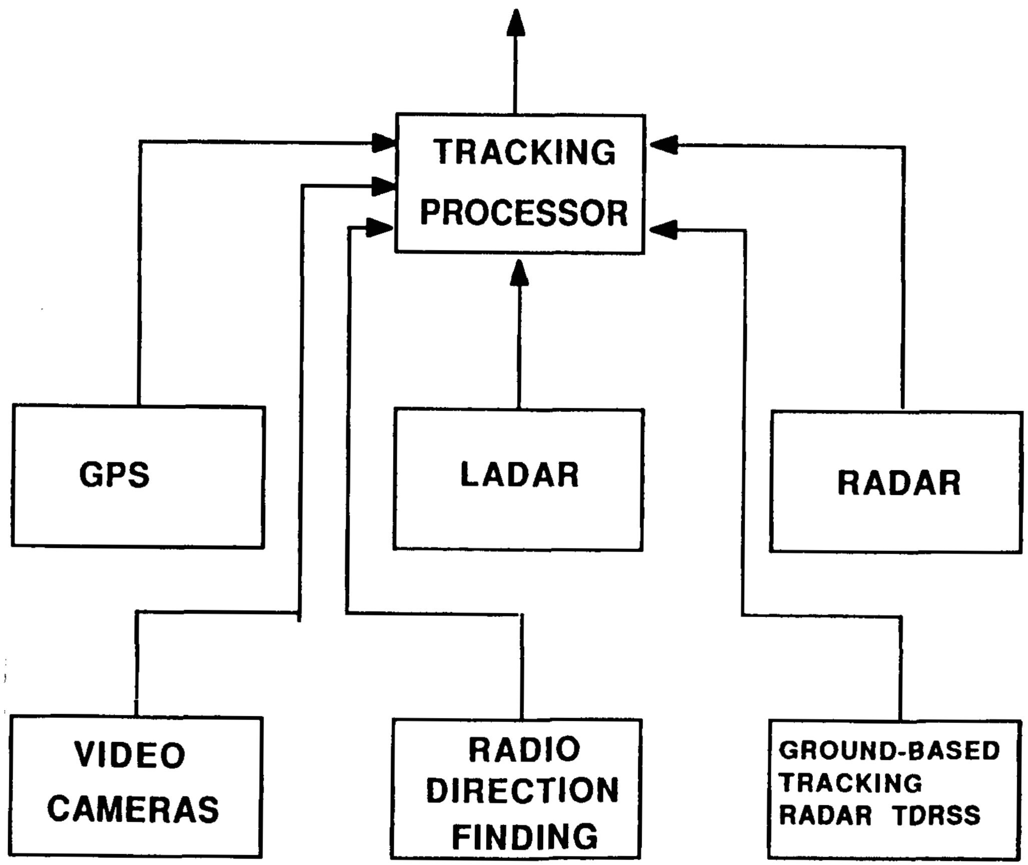
Text for The Evolution Tracking System

The block diagram shown in the facing slide relates the components of the evolution tracking system for Space Station Freedom as it is currently envisioned. Very little of the structure shown is available to Station operations at IOC. The focus of the slide, the tracking processor, is a vital recommendation. It is critical to functional growth of Freedom's orbital operations. With suitable sensors it can increase operational safety, efficiency, fault tolerance, and allow autonomy, while decreasing crew overhead, ground-based support, and docking vehicle cost.

The IOC baseline tracking configuration for the Station is currently based upon the Global Positioning System (GPS). Video cameras, while present, are primarily conceived of as manually controlled viewing aids for the astronauts. Coordination of data for tracking purposes is not possible. While the MDAC WP-2 Evolution Plan calls for the addition of a RADAR and LADAR (LAser Detection And Ranging) system, a plan for the tracking system coordinated growth with the associated processing capability has not been forged. The work here serves to coalesce such a plan, describing desired sensors, desired processing capability, and at least some of the rationale for our decisions.

Note that no quantities are given for the numbers of each species of sensory input shown in the facing slide. The optimum sensor quantities and placement issues have not been resolved, but primary considerations will be obscuration and the minimum number of viewing sensors (of specific types) to provide a given position and velocity error for given scenarios. The only sensor shown in the slide not normally considered in other work in this area is Radio Direction Finding (RDF). It is inexpensive, reasonably accurate, and requires no special action on the part of the observed party (except that he casually emit some communications or radar energy).

THE EVOLUTION TRACKING SYSTEM



Text for The Evolution Tracking System (Tracking Processor Rationale)

As mentioned on a previous slide, the tracking processor is a vital recommendation for the evolutionary requirements of the tracking system. In considering the rationale for this suggestion, there are at least three fundamental classes of scenarios which require tracking services on SS Freedom : rendezvous and docking/berthing, monitoring EVA actions (including Crew and Equipment Retrieval System -CERS- support), and the detection of approaching (baneful) objects (including debris). Each one calls for differing sensor capabilities, but common processing requirements can be identified. The last two scenarios mentioned mandate sensory capabilities onboard Freedom, and support the philosophy of a tracking processor. That is, in critical situations, speed and accuracy are required, and sometimes necessary for survival.

The rendezvous and docking class of tracking requirements is complex, but generally there can be two kinds of vehicles: those that are bristling with sensors, and those that will depend upon Freedom for approach guidance and control. For either of these vehicle classes, Station personnel must hold the rendezvous abort (veto) power (SSP 30000 specifies this for unmanned vehicles). Thus, even for craft with exemplary sensory capability, Freedom's attitude must be that of "Trust but Verify". In either case, vehicles must be tracked, and the integration of various tracking tools to support this capability calls for a tracking processor.

Perhaps the most beneficial aspect of the tracking processor will be its autonomy. It will automatically configure the available sensors to maintain maximum tracking accuracy. This implies a robust fault tolerance on the system level through the ability to generate the pointing estimates for the targets even as one sensor may fail or become obscured. The decision to abort a rendezvous for instance, would then be based solely upon the available accuracy of the state estimates for the target.

The tracking processor (with the appropriate sensors) will allow autonomous (supervised) rendezvous and docking operations at SS Freedom. Unmanned, inexpensive ELV resupply missions could be mounted for Freedom. Taking that one step further, the tracking processor philosophy is the bridge to capability in a multi-vehicle or multi-target environment. While this is not explicitly defined to be the case in most of the scenarios we have encountered, multiple target tracking and control must not be precluded (SSP 30000). It is much more possible in preparation for grand planetary missions, where many astronauts and free flyers may need to be tracked during large spacecraft assembly operations.

- IMPORTANT FOR THE THREE TRACKING SCENARIOS
  - RENDEZVOUS AND DOCKING/BERTHING
  - MONITOR EVA (CERS)
  - DETECT APPROACHING (BANEFUL) OBJECTS
- "TRUST BUT VERIFY" EVEN MANNED APPROACHES
- RESPONSIBLE FOR AUTONOMOUS TRACKING SYSTEM CONTROL (E.G. TARGET HANDOVER, OPTIMAL SENSOR ALLOCATION)
- NECESSARY FOR AUTONOMOUS RENDEZVOUS AND DOCKING/BERTHING
- REQUIRED FOR SAFE AND EFFICIENT UTILIZATION OF CREW IN MULTI-VEHICLE /TARGET ENVIRONMENTS
- ESSENTIAL FOR FAULT TOLERANCE THROUGH RAPID SENSOR RECONFIGURATION

Text for the SSF Evolution Tracking Sensor Group

The ultimate collection of sensors for SS Freedom's evolution is based upon a variety of technologies, each sensor class capable of providing some part of the tracking parameter group to a certain accuracy in a given scenario. One dependable element long used has been ground-based tracking RADARs. That, in combination with the processing of TDRSS communications data, exists as terrestrial support for Freedom operations. While ground-based tracking shall remain as a valid contingency tool, SS Freedom operational philosophy must try to move toward maximum independence from ground-based support, for safety and associated overhead cost reasons.

A powerful new tool for long and mid-range applications for low Earth orbit is the Global Positioning System. Effective use of GPS should obviate the need for ground-based tracking, although it requires that the vehicles communicate GPS information to one another. Work is currently being performed to determine what degradation may be expected from this technique as the docking craft approaches an object such as SS Freedom. GPS is the core element in developing the tracking sensor suite.

Currently in the MDAC WP-2 Evolution Plan, LADAR and RADAR afford the Station significant capability. We have chosen the title "LASER based tracking tools" to describe a class of tools which would include a LADAR sensor. The model for any LADAR type system will be the Laser Docking Sensor (LDS) being built now for a flight experiment aboard the OMV. The typical scenarios for using LDS type tools involve using retroreflectors on the targets, which offers greater range, and a simplified mechanism for orientation determination at close range. The RADAR system would offer data on targets not specifically outfitted for the LADAR (noncooperative). This would be critical for scenarios involving crew retrieval, where an EMU (or EEU) might need to be tracked to provide targeting data for equipment such as an EVA Retriever. Both the LADAR and RADAR system technology can benefit from Strategic Defense Initiative (SDI) developed space qualified versions of similar systems.

Radio Direction Finding techniques are inexpensive and a reasonably accurate means for locating casual emitters (communications or RADAR) in the Station environment. Like using camera video as a tracking tool, RDF three dimensional accuracy will be better in the mid to near range type applications. At longer ranges it will operate to deliver bearing information for pointing other sensors. It will greatly reduce acquisition time for tracking processor coordination.

Video cameras mounted across the Station for exterior viewing requirements can also be used effectively for tracking. Like RDF, accuracy is a function of the viewing geometry. This implies greatest possible baseline for maximum long range accuracy. Noncooperative attitude determination is difficult, but can be done in coordination with range images with some success. Light sources on the target are extremely beneficial for both attitude, and long range viewing. Strobe illumination from the Station can be used for long range viewing and under darkened conditions.

- GPS

  P(Y) CODE RESOLUTION

- LASER BASED TRACKING SYSTEMS

  E.G. LASER DOCKING SENSOR

- RADAR

  CCZ COVERAGE ONLY

- RADIO DIRECTION FINDING (RDF)

  S-BAND, KU-BAND, POSSIBLY X-BAND

- VIDEO CAMERAS (VARYING WAVELENGTH SENSITIVITY POSSIBLE)

- TERRESTRIAL

  TDRSS DATA, SPACE OBSERVING RADAR

Text for Tracking Processor

Inputs to the tracking processor will include both video and digital communications as shown entering the "Video Communications" and "Digital Communications" boxes in the facing slide. All video input formats will initially conform to NTSC, and should in the future be HDTV compatible (bandwidth and format). Using separate red, green, and blue channels on the initial installation would be preferable to NTSC, but the resources to accommodate differing standards and the additional communication requirements would be costly. Digital information can come both from local and remote GPS and RDF sensors, or from ground-based sources (processing TDRSS data, or space observing radar installations such as USSPACECOM). Included with the video or digital data, or built into a database, must be estimates of error so that proper modelling can be given for each data type.

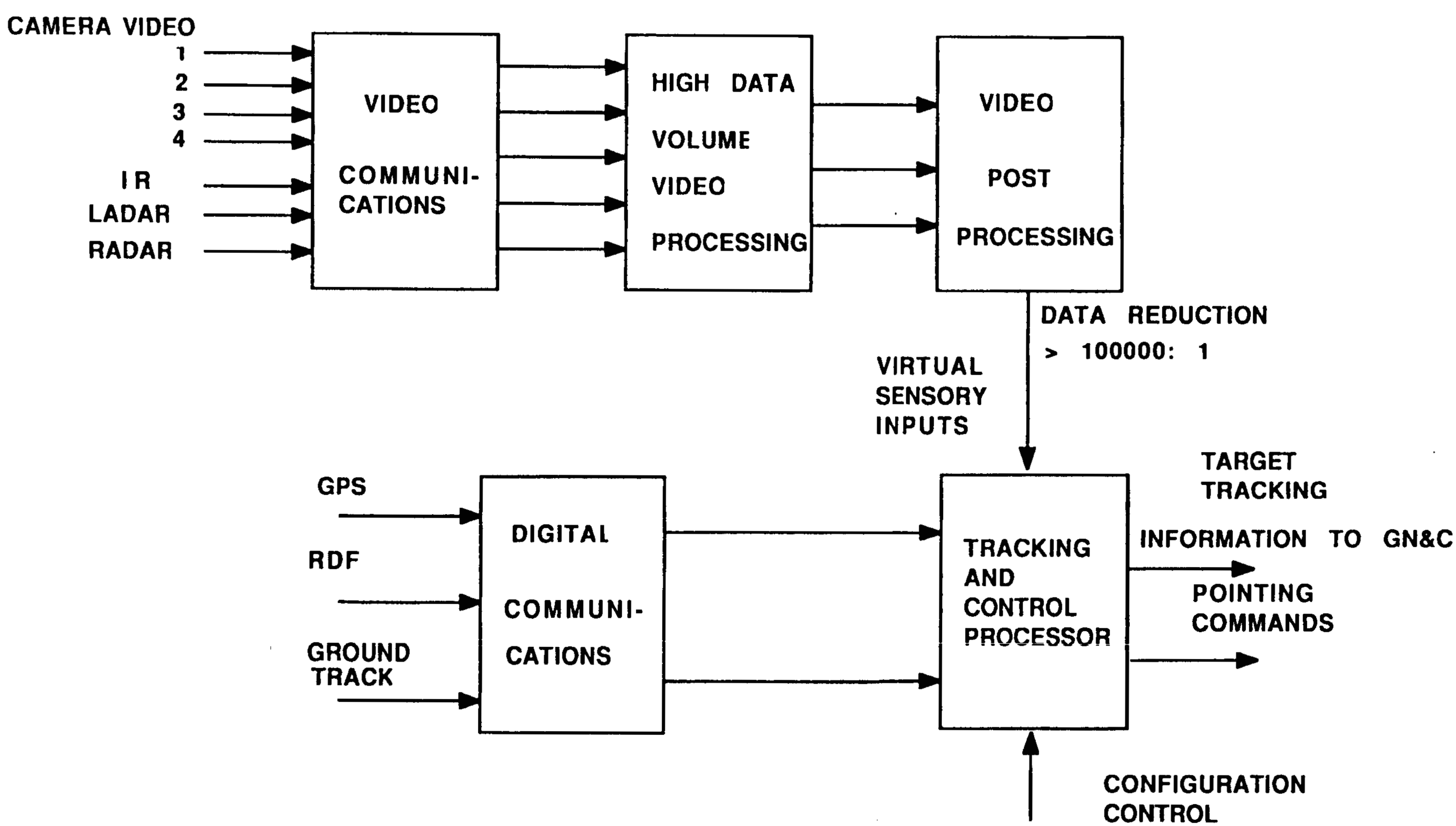
Only a subset of the video inputs can be expected to have pertinent information at one time. This may be different types of information from normal camera video to RADAR. This is passed to the video processing stages. A typical architecture is depicted, others are possible. The first step in the data reduction process is "High Data Volume Video Processing" which transforms the image information into products for the "Video Post-processing", which is more sequential in nature. Data reduction through the video processing must attain ratios of at least 100,000:1. The final product from the video processing, as it is from the digital communications, is an estimate of position and orientation.

Requiring consistency between the data representations allows the "Tracking and Control Processor" element within the tracking processor to view the remainder of the system as virtual sensors, each delivering a measure of position and orientation of the target as well as a model of its error which allows the system to be more adaptive and incorporate new virtual sensors more easily. This sub-system is responsible for weighting the position estimates from each virtual sensor, and arriving at a true estimate of target position. From this estimation, it can generate both positioning control for the sensors and any illumination corrections that can be made, as shown leaving this module in the figure.

The tracking processor system, to clarify, is responsible for measuring the position and orientation of all targets. It will control the positioning and configuration of its sensors to acquire that data. It will supply data as required to GN&C and others.

Certainly the most expensive portion of the tracking processor is the video processing, loosely consisting of the top three boxes in the figure. An initial approach to incorporating this capability may be to process only one video input at a time, but to switch or multiplex between other useful inputs as resources allow. More channels can be processed simultaneously when additional permanent resources can be installed.

When considering growth for the tracking processor, additional video-type inputs have the greatest impact. Whenever additional targets must be tracked, additional processing capability is required for the tracking and control process. But this is almost insignificant compared to the additional computational requirements needed for video processing when more sensors must be processed simultaneously.


CAMERA VIDEO
1
2
3
4
IR
LADAR
RADAR
VIDEO COMMUNI-CATIONS
HIGH DATA VOLUME VIDEO PROCESSING
VIDEO POST PROCESSING
DATA REDUCTION
> 100000: 1
VIRTUAL SENSORY INPUTS
GPS
RDF
GROUND TRACK
DIGITAL COMMUNI-CATIONS
TRACKING AND CONTROL PROCESSOR
TARGET TRACKING
INFORMATION TO GN&C
POINTING COMMANDS
CONFIGURATION CONTROL

Text for Processing Considerations

The actual processing performed in each of the main blocks of the tracking processor diagram has significant impact on the amount of computational power that must be available. For example, large volume video-data processing may use algorithms as computationally expensive as surface modeling, or as simple as edge enhancement. These algorithms suggest both conventional processing schemes like image pipeline processors and the emerging optical image processors.

Video post-processing may be more symbolic in nature such as for stereo matching or knowledge-based vision. Candidate schemes could include optical image processing on a reduced scale, or loosely-coupled parallel processors, which are receiving widespread acceptance.

The tracking and control algorithms are not less critical than the preceding algorithms and may present significant processing requirements as well. A Kalman filter of many variables can require significant vector processing. The remaining tasks can best be performed by a sequential processor.

The video processing algorithms described are, for the most part, in widespread use today and have hardware available to make the algorithms feasible in real-time systems. An example is the simple yet powerful technique of thresholding and blob analysis for targets at long range. These techniques (e.g. centroid tracking) may apply to LADAR, RADAR, or even passive electro-optic sensors when dealing with cooperative targets. The processing requirements of this class of algorithms are readily attainable for RS-170 video resolution now (at frame rates). Resolution greater than that attainable through the NTSC standard (such as HDTV), can be performed at less than frame rates, but still fast. Within the evolution time frame, higher resolution capability should also be available at frame rates.

HIGH DATA VOLUME VIDEO PROCESSING

ALGORITHMS: FUSION, JUMP-BOUNDARY DETECTION, INTENSITY GRADIENTS, CORRELATION MATCHING, PHANTOM, SUPPRESSION, STEREO MATCHING SURFACE MODELING, CONNECTIVITY ANALYSIS

HARDWARE: PIPELINE PROCESSORS, PARALLEL PROCESSORS, OPTICAL IMAGE PROCESSING

VIDEO POST PROCESSING

ALGORITHM: IMAGE CORRELATION, SENSOR FUSION, CODED TARGET DISCRIMINATION, MODEL-BASED VISION, KNOWLEDGE-BASED VISION, STEREO AND MULTI-CAMERA PROCESSING, COORDINATE TRANSFORMATIONS

HARDWARE: OPTICAL PROCESSORS, LOOSELY-COUPLED PARALLEL PROCESSORS, VECTOR PROCESSORS

TRACKING AND CONTROL

ALGORITHM: KALMAN FILTERING, CURVE REGRESSION, SENSOR POSITIONING, ILLUMINATION CONTROL, CALIBRATION

HARDWARE: VECTOR PROCESSORS, SEQUENTIAL PROCESSORS

Text for Hooks and Scars (Communications, Space-to-Ground Subsystem)

Hooks and scars will be provided for the C&T system to ensure that growth to the assembly complete functional requirements can be achieved. As a minimum scars will include cabling, brackets, and penetrations as required.

For the communications space-to-ground links. Hooks and scars shall be provided to install the Ka-band system compatible with the Advanced Tracking and Data Relay Satellite System (ATDRSS), which can support up to 50 Mbps forward link and 650 Mbps return link with increased bandwidth capability and less interference. In addition, a full rate S-band system, which provide 300 Kbps forward link and 6 Mbps return link, shall also be installed for use with ATDRSS to improve contingency data transmission capability.

In order to transmit data to selected ground stations to achieve high volumes of maximum traffic efficiency, provision for installation of a multi-beam antenna subsystem is provided. This subsystem will operate independent of Space-to-Ground TDRSS subsystem. High data rate can be transmitted to the desired ground station by pointing the appropriate antenna beam toward that station.

COMMUNICATIONS

1. SPACE-TO-GROUND SUBSYSTEM

- ADDITION OF KA-BAND SYSTEM
  - PROVIDE INCREASED BANDWIDTH CAPABILITY, LESS INTERFERENCE AND GROWTH THAT ARE INHERENT WITH ATDRSS:

    TO SUPPORT

    FORWARD LINK - 50 MBPS

    RETURN LINK - 650 MBPS

- ADDITION OF FULL-RATE S-BAND SYSTEM
  - PROVIDE INCREASED BANDWIDTH FOR USE WITH ATDRSS

    TO SUPPORT

    FORWARD LINK - 300 KBPS

    RETURN LINK - 6 MBPS

- ADDITION OF MULTI-BEAM ANTENNA SYSTEM
  - PROVIDE FOR INSTALLATION OF A MULTI-BEAM ANTENNA SUBSYSTEM INDEPENDENT OF THE SPACE-TO-GROUND TDRSS SUBSYSTEM TO TRANSMIT DATA TO SELECTED GROUND STATIONS TO ACHIEVE HIGH VOLUMES OF MAXIMUM TRAFFIC EFFICIENCY

Text for Hooks and Scars (Communications, Space-to-Space Subsystem, etc.)

For the space-to-space subsystem, fiber optic cable installation will be provided at IOC. This installation will save considerable cost when the baseline coaxial cables are replaced to increase transmission efficiency. Scars will also be provided to accommodate additional interoperating elements including interplanetary space vehicles such as lunar and Mars exploratory spacecraft. In order to support interplanetary missions at much increased communication distance, hooks and scars will be provided for upgrading of baseline space-to-space antenna size, increasing of RF power amplifier, and/or employing most efficient modulation/coding scheme.

Hooks and scars will be provided to support high definition TV (HDTV) for the Video Subsystem when the HDTV technology is mature. HDTV requires much wider bandwidth and complicated signal processing. The baseline video signal distributions are in the analog NTSC composite forms, which not only require conversions to RGB prior to being transmitted to the ground but also are easily subject to noise disturbance during transmission. Provisions for digital distributions in discrete RGB forms will be provided to improve transmission quality and efficiency. Video signal compatibility shall also be provided for interfacing with international elements.

The flat-screen technology will be integrated into the Control and Monitor Subsystem to improve display quality and reduce power, size, and weight. Provisions will be provided for the CMS to accommodate the advanced synchronous optical network (SONET). The CMS shall also be provided to integrate a special computer system for voice acquisition/recognition, language-to-text, and text-to-language capability. This capability is needed to improve command sequences and the modes of operation of the C&T system.

2. SPACE-TO-SPACE SUBSYSTEM

- PROVIDE FOR INSTALLATION OF FIBER OPTIC CABLE AT IOC
- ENABLE COMMUNICATION WITH ADDITIONAL VEHICLES (INCLUDING INTERPLANETARY)
- PROVIDE FOR UPGRADING OF ANTENNA SIZE , RF POWER AMPLIFIERS, AND/OR EMPLOYING MOST EFFICIENT MODULATION/CODING SCHEME TO SUPPORT INCREASED COMMUNICATION DISTANCE (INCLUDING MOON AND MARS)

3. VIDEO SYBSYSTEM

- PROVIDE FOR PROVISIONS TO SUPPORT HIGH DEFINITION TV, DISTIBUTIOIN SYSTEM DIGITIZATION FOR TRANSMISSION TO GROUND STATION, AND INTERFACE WITH INTERNATIONAL ELEMENTS

4. CONTROL AND MONITOR SUBSYSTEM

- INTEGRATION OF FLAT-SCREEN TECHNOLOGY AND INTERFACES INTO CMS
- ACCOMMODATION OF AN EVOLUTIONAL ADHERENCE TO THE SYNCHRONOUS OPTICAL NETWORK (SONET)
- INTEGRATION OF COMPUTER SYSTEM FOR VOICE ACQUISITION/RECOGNITION, LANGUAGE-TO-TEXT AND TEXT-TO-LANGUAGE CAPABILITY

5. AUDIO SUBSYSTEM

- INTEGRATION OF AUDIO SIGNAL FORMATS INTO INTEGRATED SERVICE DIGITAL NETWORK (ISDN)

Text for Hooks and Scars (Tracking)

Part of the philosophy of the SSF evolution tracking system design has been to minimize the resultant scarring. To help accomplish this, the sensor node concept was put forth (described in more detail below.) Due to the lack of sensor processing capability existing in the IOC design however, scarring for the tracking processor has taken on a more significant nature. The tracking processor as it has been defined here must have fast response to switching requests on the video bus. It must control selection of video sources, and timing of video synchronization. Today's technology for video rate processing offers a significant scar for both volume and power. A card cage full of video rate pipeline may use almost a kilowatt of power, and occupy a quarter rack space.

Sensor hooks and scars are less significant to Station conceptualization. Creating sensors compatible with the fiber optic video acquisition network on the exterior of the Station guarantees the ability to move them as necessary, and acquire data at up to 20 MHz. Thus, RADAR and LADAR units which have been designed to the sensor node network standard, require no scarring for installation. As node members, each would be identified, and any special processing algorithms required for tracking using that sensor would be loaded. It mildly compounds the duty of the tracking processor software to have sensor variety, but the flexibility offered for exterior reconfigurability greatly outweighs the software issue.

Sensors which would provide only small amounts of digital data will not benefit from sensor node placement. Techniques such as RDF will use low data rate communications such as the Station's LAN service. Depending upon the ultimate positioning of the RDF receivers, special LAN runs may have to be made to support communications. Depending upon the update rate that is forced on the RDF system, a direct RF link between one or more of the units may also be necessary.

TRACKING

- PROVIDE FOR INSTALLATION OF A TRACKING PROCESSOR
  - MUST CONTROL IOC VIDEO CROSS POINT SWITCH/MUX, AND VIDEO TIMING
  - UP TO 1 RACK VOLUME DEPENDENT ON TECHNOLOGY USED
  - UP TO SEVERAL KILOWATTS OF POWER (DEP. ON TECH. USED)
- PROVIDE FOR INSTALLATION OF A RADAR
  - IF SENSOR NODE COMPATIBLE, NO SCARRING
  - HOOKS PRIMARILY TO TRACKING PROCESSOR
- PROVIDE FOR INSTALLATION OF A LADAR
  - IF SENSOR-NODE COMPATIBLE, NO SCARRING
  - HOOKS PRIMARILY TO TRACKING PROCESSOR
- PROVIDE FOR INSTALLATION OF AN RDF SYSTEM
  - MAY NEED RF LINK BETWEEN UNITS
  - DATA OUTPUT COULD USE DMS LAN OR PAYLOAD LAN
  - HOOK PRIMARILY TO TRACKING PROCESSOR

Text for Hooks and Scars (Tracking, Continued)

The term Sensor Node Network describes a slightly modified version of the Station video network ensuring long term growth of the tracking system through reconfigurability. Sensor identification and commands can continue to be placed using video timing windows, but the nature of the command groups should be broadened to enable operation with other types of sensors. Important scarring must exist to have sufficient coverage of the network to allow growth and alteration. The sites should be regular and widely distributed. The nodes can be designed to be inexpensive, and might number from tens of sites to one hundred sites. With appropriate thought given to the choice of connectors (etc.), EVA astronauts and pieces of automation may feed high bandwidth (secure) communications to and draw power from, the sensor node network.

One issue of importance for a reconfigurable system must be that of calibration. The ultimate accuracy of the system depends upon the pointing error of each of its components. The position of each of the node sites may not be accurately known, and structural obscuration may change over long periods as the Station evolves. The pointing may also be affected by structural composition for electromagnetic techniques. Thus, position, viewing envelope, and pointing deviation (if any) must be identified for the network elements. There are many possible calibration methodologies. Scarring must include fiducials for each of the sensor groups on and off the Station. Small sites on the Station including pointing targets, luminous point sources, and retroreflectors are inexpensively arranged. Also recommend some form of a remote (possibly tethered) fiducial, which may be moved a known distance away in a controlled direction, to offer similar services. The off Station fiducial would support RADAR and RDF calibration, in addition to offering a more realistic test and calibration environment for the other sensors.

TRACKING (CONTINUED)

- PROVIDE FOR MANY MORE SENSOR NODES (VIDEO COMPATIBLE)
  - SS FREEDOM GROWTH WILL REQUIRE RELOCATION AND ADDITION OF VARIOUS SENSORS (VIDEO CAMERAS, LADAR, RADAR) IMPLYING:
    - POWER AND BIDIRECTIONAL COMMUNICATIONS SENSOR NODES SHOULD BE PLACED AT REGULAR INTERVALS ALONG STATION STRUCTURE
      - SCAR FOR MORE VIDEO NODES
      - BETTER COMMUNICATIONS FOR EVA ACTIVITIES
    - SENSORS MUST HAVE A COMPATIBLE COMMUNICATIONS SCHEME TO ALLOW SENSOR NODE INDEPENDENCE (VIDEO BASED)
    - CALIBRATION SCHEME MUST BE DEVISED TO ACCOUNT FOR RECONFIGURABILITY
      - FIDUCIALS ON SSF
      - FIDUCIAL ON A TETHER