SPACE STATION FREEDOM
CENTRAL THERMAL CONTROL SYSTEM EVOLUTION

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OBJECTIVE

IDENTIFY PRINCIPAL HOOKS AND SCARS FOR SSF TCS GROWTH

TYPES OF GROWTH

- RESOURCE GROWTH - PHYSICAL EXPANSION
- TECHNOLOGY GROWTH - HARDWARE OBSOLESCENCE AND INSERTION

GROWTH PERSPECTIVE

- SPACE STATION EVOLUTION DEFINITION - NASA LaRC
  - R & D Node - Technology/Commercial Mission
  - Transportation - Exploration Mission
- STATE OF THE TCS BASELINE
  - CTB Selection, 1ø/2ø Requirement, BMR's, etc ...
  - Program Rephasing in Late 1989 --> NO GROWTH

AGENDA

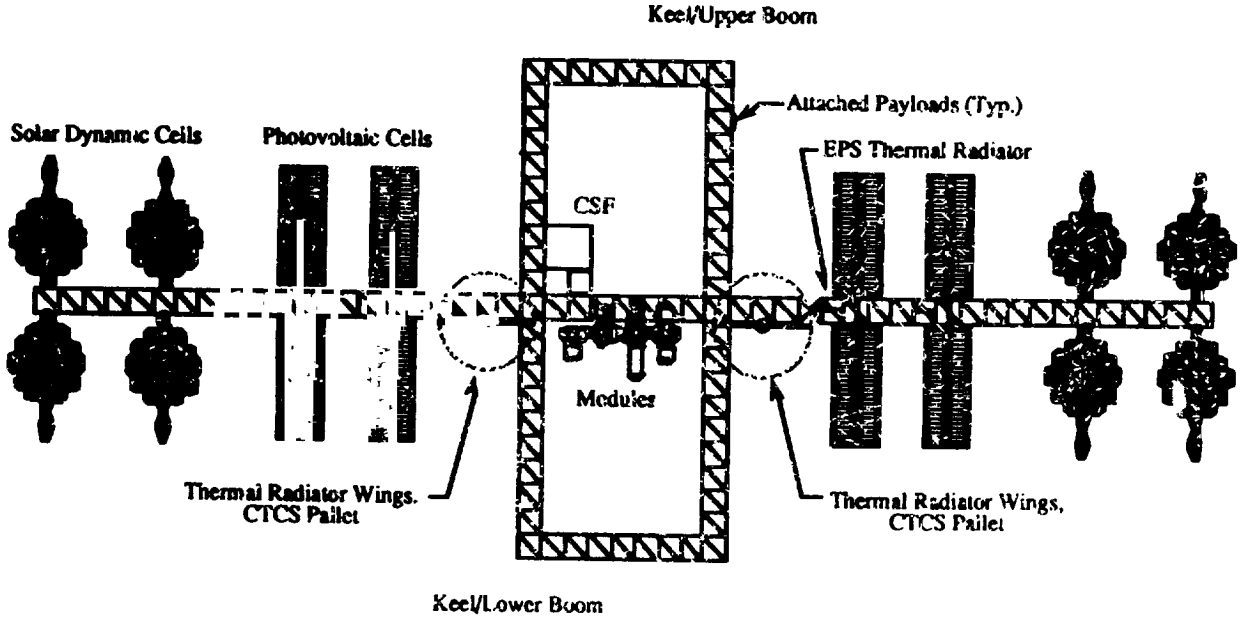
- REVIEW GROWTH REQUIREMENTS AND BASIC FEATURES OF R & D AND TRANSPORTATION NODES
- IDENTIFY THE PRINCIPAL CTCS HOOKS AND SCARS AT ASSEMBLY COMPLETE TO ACCOMMODATE GROWTH
- DESCRIBE THE GENERAL PROVISIONS FOR GROWTH AND IDENTIFY PERTINENT DESIGN ISSUES
- CONCLUSIONS

REQUIREMENTS FOR GROWTH

TCS REQUIREMENT	APPLICATION
HEAT REJECTION CAPABILITY	75 kW (82.2 kW) --› 300 kW (325) or 181kW (200)
ON ORBIT RECONFIGURATION	VARIABLE TEMPERATURE LEVEL, HEAT LOAD
MODULARITY	SPACE ERECTABLE, REPLACEABLE
SAFETY	95% MINIMUM OPERATIONAL CAPABILITY
LEAK DETECTION	5% PER YR (PER LOOP) MAX LEAKAGE
QUIESCENT OPERATION	10% OF FULL LOAD
REDUNDANCY	TWO FAULT TOLERANCE
ISOTHERMALITY	±2.0°C
MONITOR & CONTROL	MINIMUM CREW INVOLVEMENT
TECHNOLOGY ACCOMMODATION	NO SYSTEM INTERUPTION

RESEARCH & DEVELOPMENT NODE

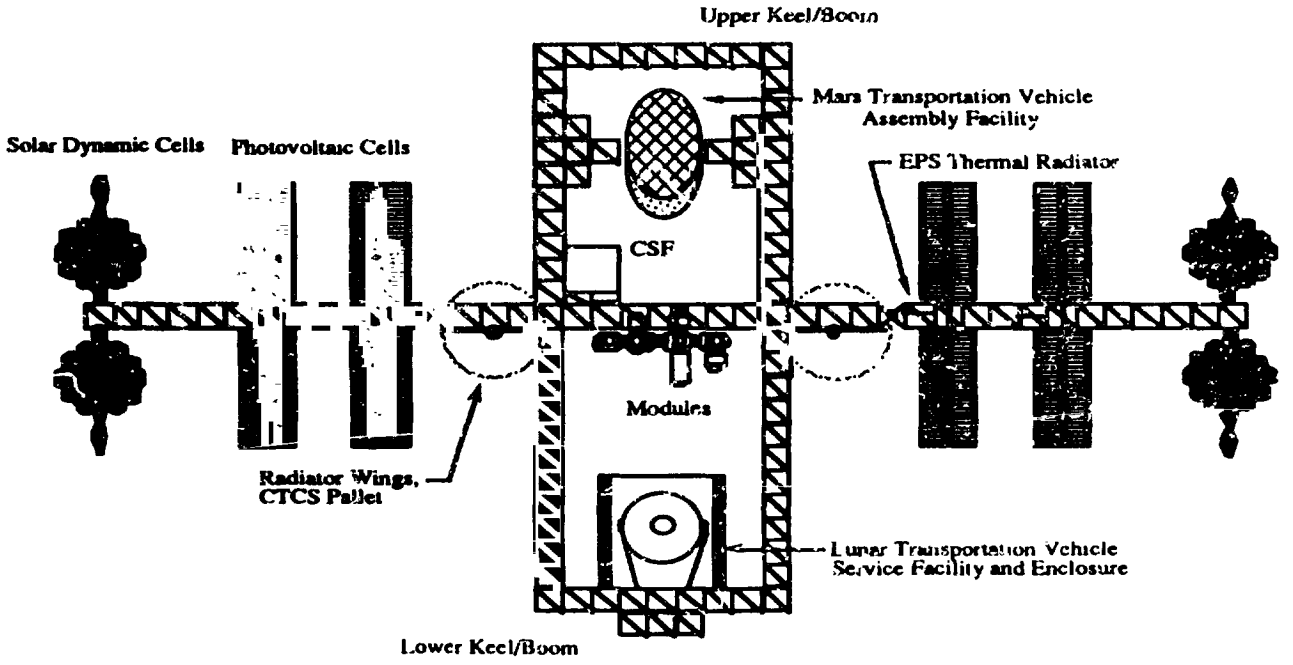
RESOURCES:	
POWER	300 kW
THERMAL	325 kW
CREW	18
MODULES	3 Hab, 3 Lab, 2 Intn'l, 8 Nodes, 3 Pocket Lab, 2 Airlocks, 1 Logistics
SERVICING	CSF
APAE	5 Transverse Boom, 13 Dual Keel
STRUCTURE	17-A-15-A-17; Keel/Boom 10 x 9 Bays



TRANSPORTATION NODE

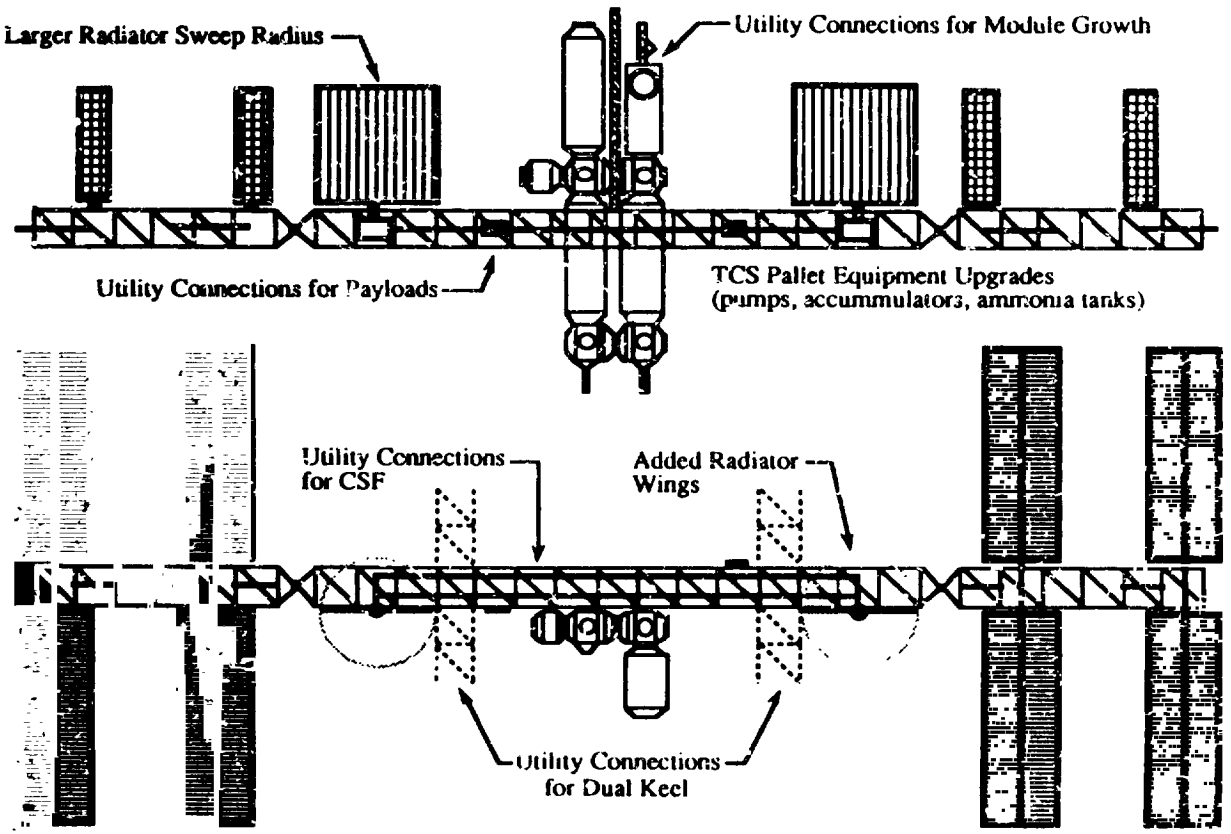
RESOURCES:

POWER	181 kW
THERMAL	200 kW
CREW	16 + 9 Transient
MODULES	3 Hab, 1 Lab, 2 Intn'l, 8 Nodes, 1 Pocket Lab, 2 Airlocks, 1 Logistics
SERVICING	CSF, LTV (+ Enclosure), MTV
APAE	8 (location TBD)
STRUCTURE	12 [illegible]5-A-12; Lower Keel/Boom 12 x 9, Upper Keel/Boom 11 x 9 Bays



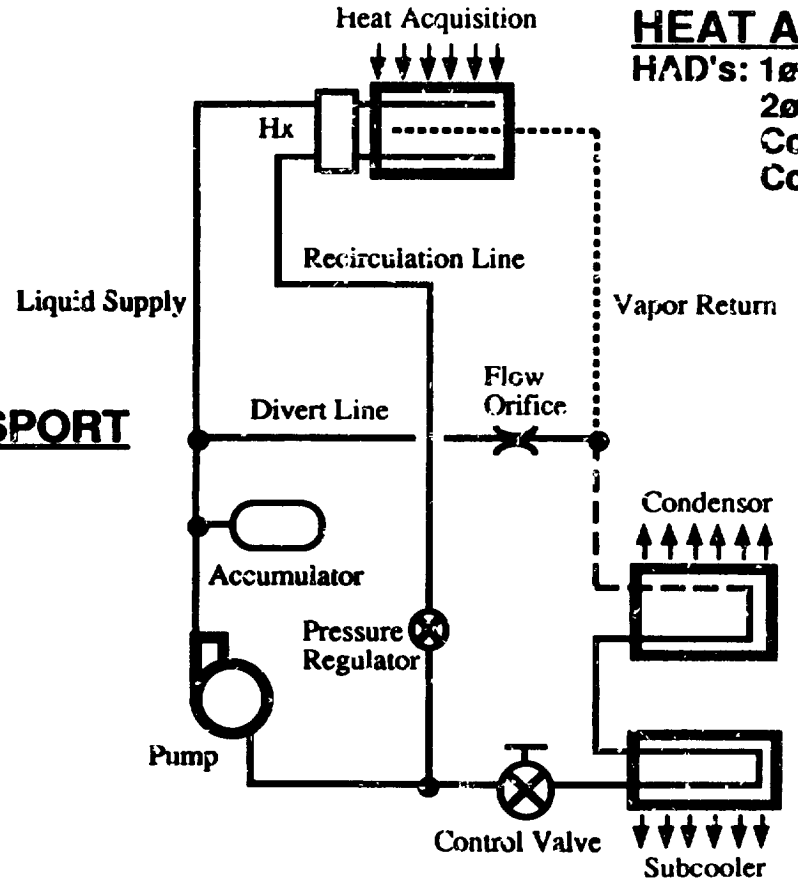
PRINCIPAL SCARS

PRINCIPAL SCARS FOR R & D NODE OR TRANSPORTATION NODE ARE SIMILAR



Expansion of TCS Monitoring & Controls Subsystem (shared SPD and MDM's)

CTCS FLOW SCHEMATIC AND SUBSYSTEMS



HEAT ACQUISITION
HAD's: 1ø-H2O/2ø-NH3 HX
2ø-NH3/2ø-NH3 HX
ColdPlates
Coldrails

THERMAL TRANSPORT
Transport Lines
Valves, QD's
Pallet Equipment

HEAT REJECTION
Radiator Panels
Condensers
Subcoolers
Rotary Fluid Coupler

HEAT ACQUISITION GROWTH

RESOURCE	AC		R & D		TRANS	
	UNITS	HX/CP	UNITS	HX/CP	UNITS	HX/CP
MODULES	2 US, 2 I	12	6 US, 2 I	28	4 US, 2 I	20
RESOURCE NODES	4	8	8	16	8	16
POCKET LABS	-	-	3	6	1	2
ATTACHED PAYLOADS	-	-	18	36	8	16
CSF	-	-	1	3	1	3
LTV + MTV FACILITY	-	-	-	-	1	4
DDCU COLDPLATES	20	20	52	52	40	40
TOTAL HX(1)	40		141		101	
TOTAL WEIGHT (LBS)	4660		15570		10890	

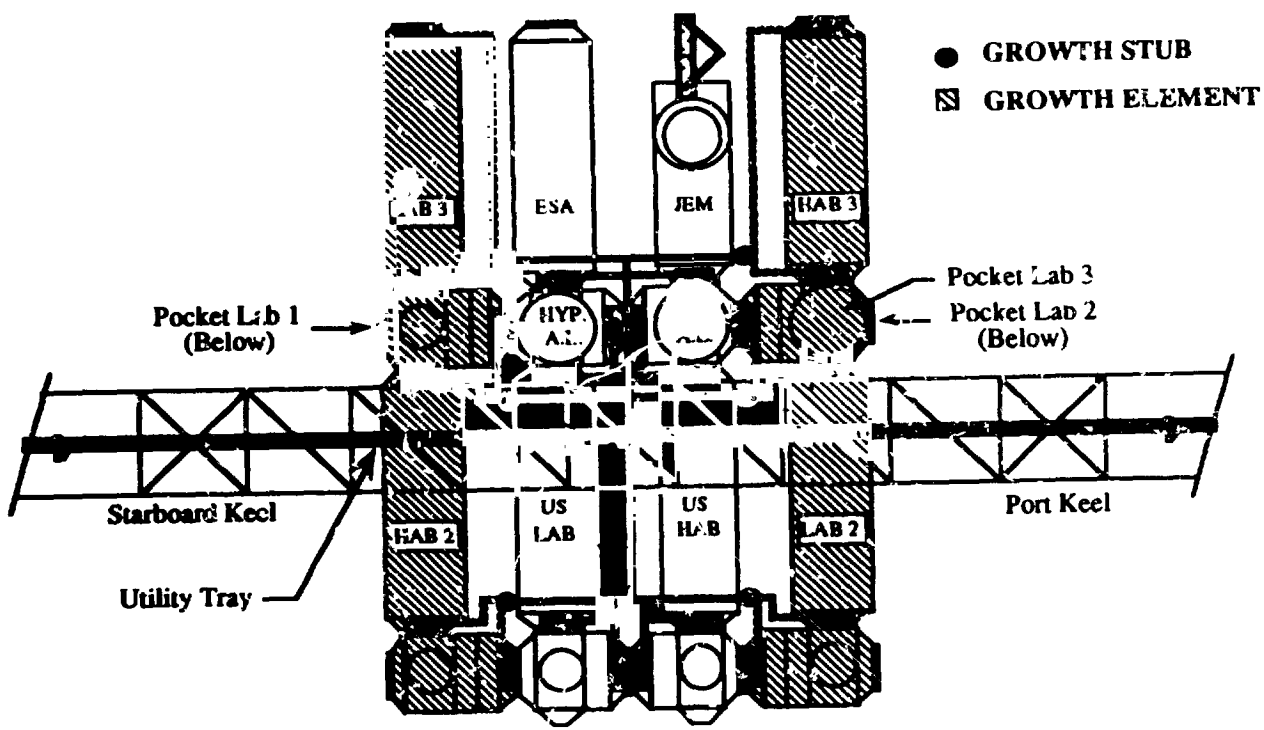
PROVISIONS FOR GROWTH

- MODULE, POCKET LAB, AND NODE HEAT EXCHANGERS INTERFACE WITH SECONDARY FEED (FORE & AFT) BRANCHING FROM TRANSVERSE BOOM. THE SECONDARY FEED BRANCH WILL REQUIRE STUBS FOR GROWTH.
- VARIABLE FLOW ORIFICES WILL BE REQUIRED FOR CAPILLARY HAD'S TO ACCOMMODATE ADJUSTMENTS IN SYSTEM PRESSURE AND FLOW RATES ASSOCIATED WITH PHASED GROWTH.

(1) EACH HEAT EXCHANGER UNIT HAS SIX INLET/OUTLET PORTS FOR FLUID CONNECTIONS WITH THE PRIMARY AND REDUNDANT THERMAL LOOPS

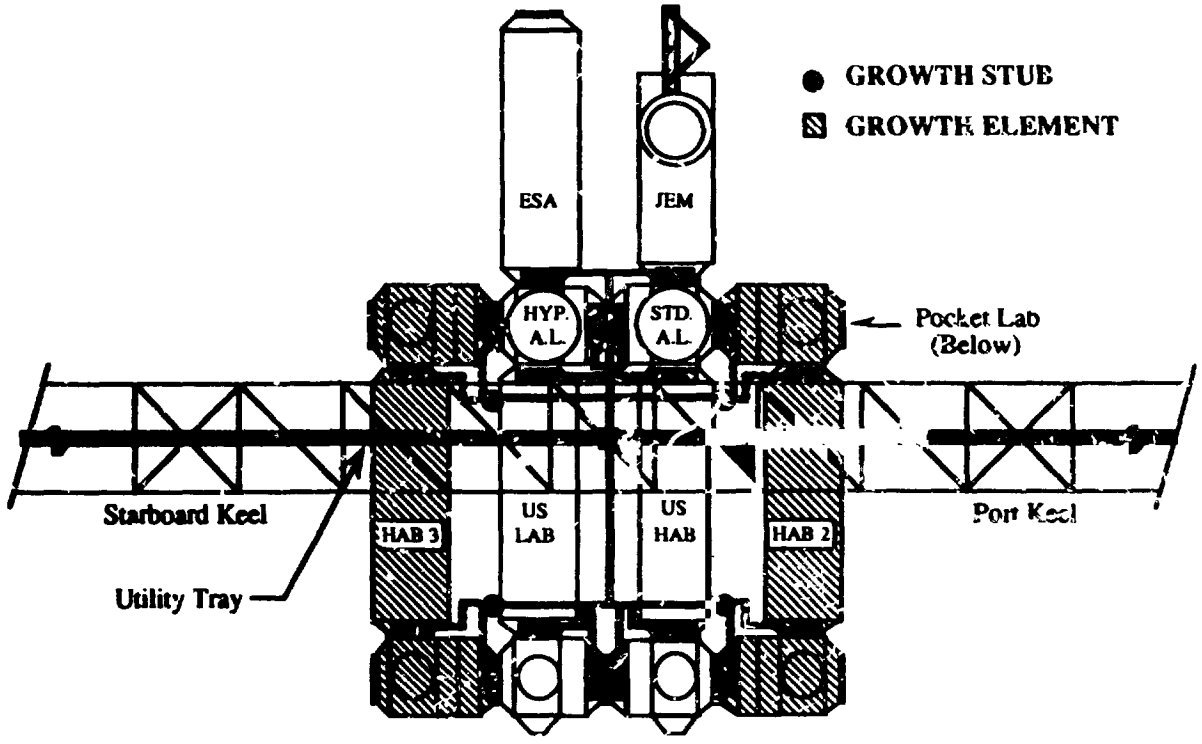
R & D MODULE ATCS FLUID DISTRIBUTION (PRELIMINARY)

MODULE GROWTH IS IN THE ±Y DIRECTION. GROWTH STUBS ARE TO BE PROVIDED ON THE SECONDARY ATCS FLUID DISTRIBUTION BRANCH.



TRANSPORTATION MODULE ATCS FLUID DISTRIBUTION (PRELIMINARY)

MODULE GROWTH IS IN THE ±Y DIRECTION. GROWTH STUBS ARE TO BE PROVIDED ON THE SECONDARY ATCS FLUID DISTRIBUTION BRANCH.



UTILITY DISTRIBUTION SYSTEM GROWTH

ITEM	AC	R&D	TRAN.
LINE LENGTH (FT)	7000	13415	13605
VALVES/QD'S	390	1005	895
TOTAL WEIGHT (LBM)	1610	11170	9660

PROVISIONS FOR GROWTH

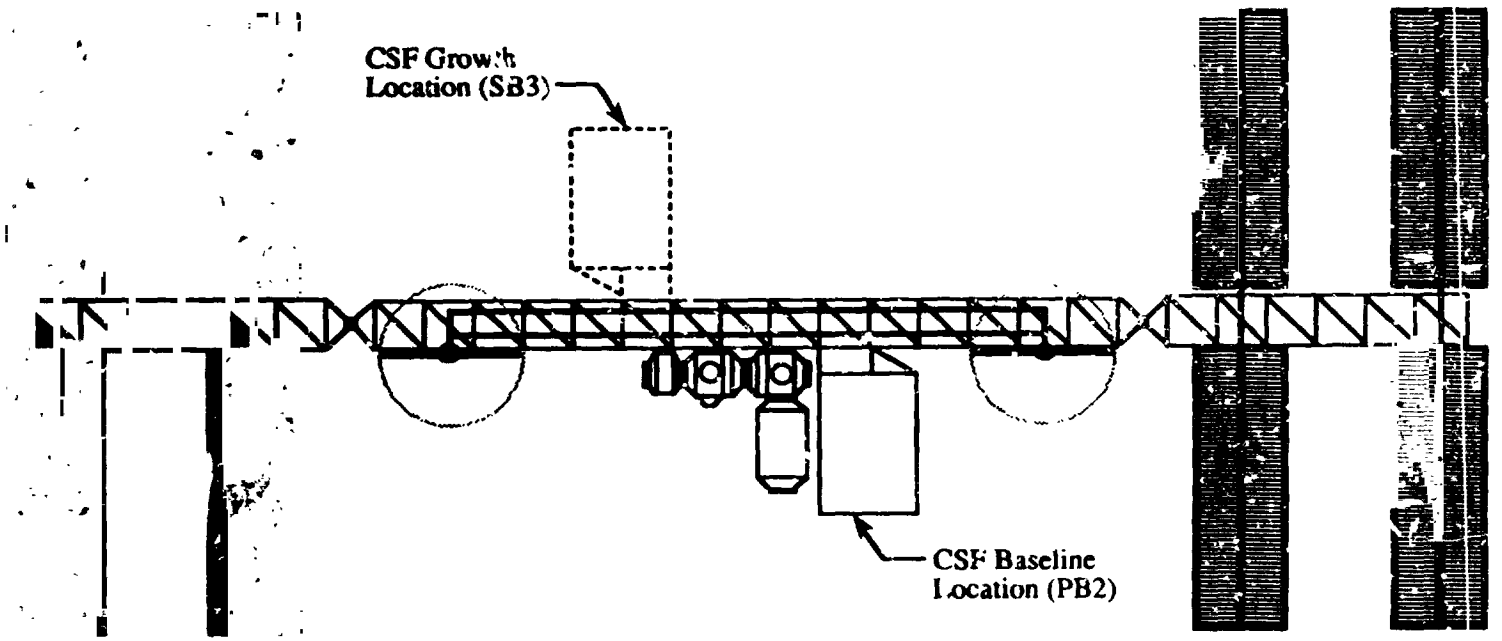
- LINES, VALVES, AND QD'S ARE SIZED FOR GROWTH
- DEPLOYABLE "POP-UP" UTILITY PORTS REQUIRED FOR DUAL KEEL (PB4,SB5) AND CUSTOMER SERVICE FACILITY (SB3)

DESIGN ISSUES

- TCS GROWTH REQUIREMENTS FOR DMS, GN&C, C&T, AND EVA HAVE YET TO BE SPECIFIED.
- PTCS IS BASELINED FOR ATTACHED PAYLOADS AND PALLETS. PASSIVE HEAT REJECTION HAS RESTRICTED VIEWING REQUIREMENTS THAT MAY BE DIFFICULT TO PRESERVE WITH GROWTH. UTILITY PORTS WILL BE REQUIRED IF ACTIVE COOLING IS REQUIRED IN THE FUTURE.
- THERMAL REQUIREMENTS FOR DUAL KEEL ARE NEEDED FOR TCS GROWTH PLANNING.
- CSF GROWTH LOCATION NEEDS TO BE BASELINED

CUSTOMER SERVICE FACILITY

- A UTILITY PORT [illegible] THE CSF SHOULD BE PROVIDED AT SB3. THE CSF WILL BE RE[illegible]ATED OR REBASELINED TO ACCOMMODATE MODULE EXPAN[illegible] (ATCS REQUIREMENTS = 25 kw)
- PRESENCE OF CS[illegible] CAUSES 1% (β=0) to 5% (β=52) REDUCTION IN HEAT REJECTION RATE



TCS PALLET GROWTH

QUANTITY DOESN'T CHANGE - ONLY SIZE

PROVISIONS FOR GROWTH

- FLUID HANDLING (ORU) EQUIPMENT IS INITIALLY SIZED FOR ___ kW. UPGRADING EQUIPMENT TO LARGER CAPACITY EQUIPMENT MAY REQUIRE INCREASED VOLUME ALLOCATION
  - PUMPS (8)
  - ACCUMULATORS (2)
  - FILTERS (8)
  - NCG TRAPS (4)
- LARGER FILL AND DRAIN TANKS WILL TO ACCOMMODATE ADDED AMMONIA INVENTORY WITH ADDITION OF DUAL KEEL (INCREASES FROM 1600 LBM TO 3200 LBM)
- VOLUME ALLOCATION FOR ADDED FORWARD ROTARY FLUID COUPLERS REQUIRED ON EACH PALLET
- TCS FLUID CONNECTIONS REQUIRED IN EACH LOOP FOR ADDED ROTARY FLUID COUPLERS

HEAT REJECTION GROWTH

ITEM	AC	R & D *	TRAN *
RADIATOR WINGS	2	4	4
HEAT REJECTION SYSTEM			
Radiator Panels	74	280	172
Condenser Panels	14	48	32
SUBCOOLING SYSTEM			
Radiator Panels	8	16	16
Subcooling Modules	4	4	4
SWEEP RADIUS (FT) **	26	46	29
TOTAL WEIGHT (LBM)	12075	39835	26400

* ASSUMES 5% SAFETY FACTOR, AND 36% @ 2°C AND 64% @ 21°C
** ASSUMES 3 INCH PANEL SPACING

PROVISIONS FOR GROWTH

- CONDENSERS ARE MODULAR AT FIXED (6 PANEL) EXPANSION INCREMENTS
- CTB CONDENSER SUPPORT STRUCTURE MUST BE MODULAR OR INSTALLED AT ASSEMBLY COMPLETE FOR FULL COMPLEMENT OF RADIATORS
- SWEEP VOLUME FOR THERMAL RADIATOR WINGS FORE AND AFT OF TCS PALLETS MUST BE PRESERVED

HEAT REJECTION GROWTH ... Con't

DESIGN ISSUES

- PANEL-TO-PANEL RADIATOR SPACING AFFECTS RADIATOR TOTAL SWEEP DIMENSION. FOR R & D NODE, WITH 1 INCH PANEL SPACING ONLY 2.6 FT CLEARANCE IS AVAILABLE BETWEEN CTCS AND EPS THERMAL RADIATORS. THE REQUIRED EVA CLEARANCE IS 7 FT .
- HEAT LOAD SPLIT BETWEEN 2°C AND 21°C THERMAL LOOPS AFFECTS TOTAL NUMBER OF PANELS (36% LOAD ON 2°C BUS, 64% LOAD ON 21°C BUS). THIS LOAD FRACTION IS SUBJECT TO CHANGE.
- PRESENCE OF CSF REDUCES RADIATOR HEAT REJECTION BY 1% (ß=0) to 5% (ß=52).

MONITORING & CONTROL GROWTH

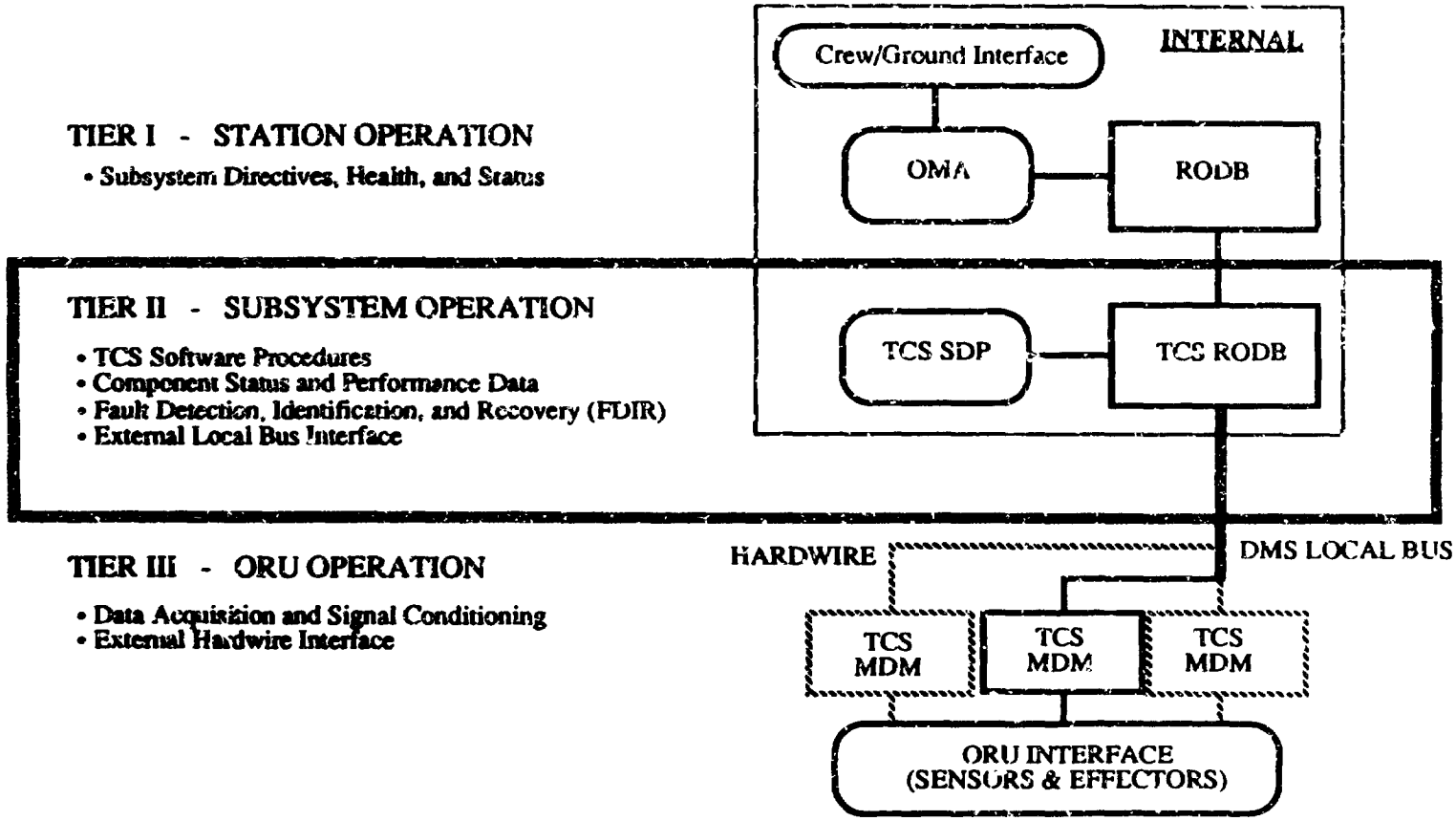
MAJOR FACTORS

- TCS PHYSICAL EVOLUTION - ADDED ORU'S, DISTRIBUTION LINES
- TECHNOLOGY EVOLUTION = "EXPERT SYSTEMS"
  - TASK ORIENTED COMMANDS —› GOAL DRIVEN COMMANDS
  - FDIR —› FAULT PREDICTION, TREND ANALYSIS

PROVISIONS FOR GROWTH

- TIER III - EXTERNAL SCARS
  - ADDED SENSORS (T, P, ΔP, Q) INCREASE FROM 675 TO 1050. EXPERT SYSTEM TECHNOLOGY WILL INCREASE THIS FURTHER.
  - VOLUME ALLOCATION FOR MDM'S. TOTAL NUMBER OF SIGNALS INCREASE FROM 4200 TO 12000. THIS TRANSLATES TO 120 ADDED MINI-MDM'S (64 PORTS EA).
  - LOCAL BUS INTERFACE PORTS FOR ADDED MDM'S
- TIER II - INTERNAL HOOKS
  - (SDP) SOFTWARE UPGRADES
  - (RODB) INCREASED MEMORY ALLOCATION
  - (LOCAL BUS) INCREASED COMMUNICATION CAPACITY REQUIREMENTS
- TIER I - INTERNAL HOOKS
  - SOFTWARE ENHANCEMENTS

TCS MONITORING AND CONTROL HIERARCHY



TECHNOLOGY GROWTH

- **ACADEMIC ISSUES**
  - TWO-PHASE FLOW TECHNOLOGY
  - THERMO-OPTICAL COATING MATERIALS
- **COMPONENT LEVEL ISSUES - GROWTH THROUGH MODULARITY**
  - BIGGEST IMPACT: HEAT PIPE RADIATORS
    - GOVERNS TOTAL HEAT REJECTION CAPABILITY
    - LARGEST WEIGHT COMPONENT IN CTCS ~ 65%
    - LARGE SWEEP VOLUME ALLOCATION
- **SYSTEM LEVEL ISSUES - INTEGRATION ISSUES = HOOKS AND SCARS**
  - ADVANCED HEAT PIPES - ARTERIAL FLOW, COMPOSITES, ETC
  - HEAT PUMP CYCLE - HIGHER TEMPERATURE FOR HEAT REJECTION PURPOSES
  - CONDENSERS - INTEGRAL CONCEPTS
  - INSTRUMENTATION - TWO-PHASE VOID FRACTION, LEAK DETECTION
  - MONITORING AND CONTROLS - EXPERT SYSTEMS

CONCLUSIONS

- INITIAL SCAR ASSESSMENT FOR "R & D NODE" AND TRANSPORTATION NODE IS COMPLETE. THE PRINCIPAL SCARS FOR EACH CONFIGURATION HAVE BEEN IDENTIFIED. THE SCARS PERTAIN TO:
  - (1) FLUID CONNECTIONS FOR MODULES, PAYLOADS, DUAL KEEL, SERVICING FACILITIES, AND RFC.
  - (2) VOLUME ALLOCATION FOR THERMAL RADIATORS AND MDM'S.
- CLEARANCE BETWEEN CTCS AND EPS THERMAL RADIATORS FOR THE R & D NODE IS A POTENTIAL PROBLEM, WHICH S LINKED TO THE MINIMUM PANEL-TO-PANEL RADIATOR SPACING. FOR THE TRANSPORTATION NODE, PHYSICAL AND EVA CLEARANCE IS PROVIDED.
- THE CTCS COMPONENT THAT HAS THE IMPACT ON GROWTH IS THE THERMAL RADIATOR (VOLUME ALLOCATION, WEIGHT, AND PERFORMANCE)
- SOFTWARE AND AUTOMATION APPLICATION DEVELOPMENT IS STILL AT "INFANCY STAGE". THIS INSTILLS A LEVEL OF UNCERTAINITY WITH REGARD TO GROWTH REQUIREMENTS. FOR EXPERT SYSTEMS THE NEED FOR ADDITIONAL SENSORS, MDM'S, AND DEDICATED TCS PROCESSORS IS EXPECTED.
- TRUSS MOUNTED EQUIPMENT (APAE'S, PALLETS) USING PTCS SHOULD INCLUDE BLOCKAGE EFFECTS DUE TO GROWTH, OR ACCOMMODATION FOR FUTURE CONNECTION TO THE CTCS SHOULD BE PROVIDED.
- A STRONG EMPHASIS HAS BEEN PLACED ON MODULARITY IN BASELINE REQUIREMENTS WHICH HAS PROVIDED FLEXIBILITY TO ACCOMMODATE GROWTH