THERMAL MANAGEMENT FOR HIGH POWER SPACE PLATFORM SYSTEMS

Richard A. Gualdoni
National Aeronautics and Space Administration
Washington, D.C.

Spacecraft designed to accomplish the requirements for long term orbital applications missions planned for the late 1980's and 1990's in which large amounts of electrical energy are generated and utilized will introduce major thermal control and thermal management problems that will challenge current technology capabilities.

In the past thermal management was not an overriding factor in spacecraft design and in general the dissipation of waste heat and the control of spacecraft and instrument temperatures was considered to be a local temperature control problem. This was a reasonable approach when only small amounts of heat were required to be dissipated and which could easily be accommodated with passive techniques.

With future spacecraft power requirements expected to be in the order of 100 to 250 kilowatts and orbital lifetimes in the order of five to ten years, new approaches and concepts will be required that can efficiently and cost effectively provide the required heat rejection and temperature control capabilities.

In October 1979, OAST initiated the planning to develop the commensurate technologies necessary for the thermal management of a high power space platform representative of future requirements. The plan to be developed was to achieve technology readiness by 1987. Representatives of Goddard Space Flight Center, Marshall Space Flight Center, Johnson Space Center, Lewis Research Center, and Air Force Wright Aeronautical Laboratories actively participated in the development of the plan. The approach taken in developing the program was to view the thermal requirements of the spacecraft as a spacecraft system rather than each as an isolated thermal problem. The program resulting from these efforts are described in the attached charts.

The program plan proposes 45 technology tasks required to achieve technology readiness. Of this total, 24 tasks were subsequently identified as being pacing technology tasks and were recommended for initiation in FY 1980 and FY 1981. The balance of the tasks were proposed for initiation in FY 1982 and FY 1983.

Initiation of the program is currently underway with funding of $600,000 to be provided in FY 1980. This is short of the $860,000 recommended for FY 1980, however, this does enable all the proposed tasks to be initiated. It is planned that future year funding will adhere to the recommendations of the plan.

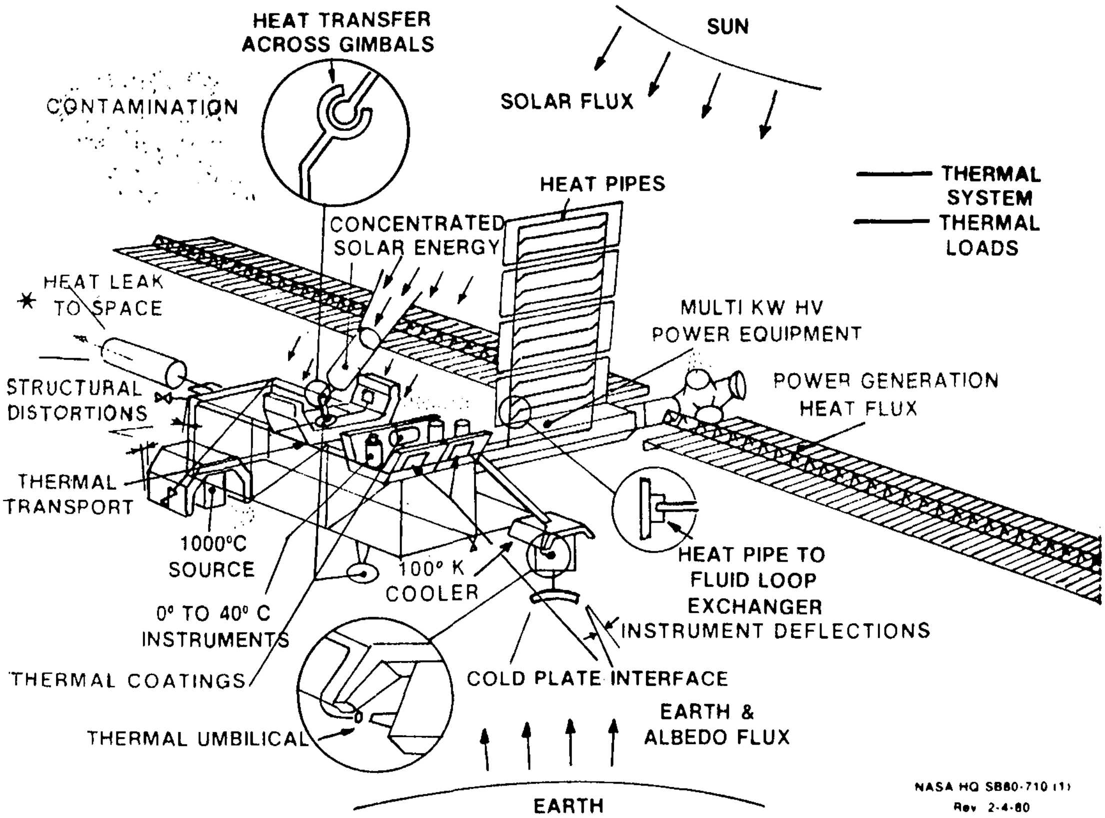
TECHNOLOGY DEVELOPMENT REQUIREMENTS AND ISSUES

- IMPROVED THERMAL ACQUISITION AND TRANSPORT TECHNIQUES
  - HIGH HEAT FLUX COOLING OF POWER GENERATION SYSTEMS (SUCH AS CONCENTRATORS)
    - HIGH DENSITY COLDPLATE
    - EQUIPMENT INTEGRAL HEAT PIPE
    - COOLING HIGH VOLTAGE EQUIPMENT SYSTEMS
  - HEAT TRANSPORT ACROSS JOINTS
    - FLUID OR HEAT PIPE GIMBALS
    - HEAT PIPE/FLUID INTERFACE HEAT EXCHANGER
    - THERMAL UMBILICAL
  - MULTIPLE SYSTEM ACQUISITION HEAT PIPE
  - THERMAL ENERGY STORAGE MATERIALS/TECHNIQUES
- ADVANCED HEAT REJECTION CONCEPTS
  - LIGHTWEIGHT (ESP. GEOSYNC.)
  - MINIMUM LAUNCH VOLUME
  - DEPLOYABLE/CONSTRUCTABLE RADIATORS
  - MODULAR FOR GROWTH
  - HEAT PIPE ADVANCES OVER PUMPED FLUID RADIATORS
  - ACCOMMODATE SPACE ASSEMBLY/REPAIR/REPLACEMENT
  - MINIMIZE DEPLOYED AREA/HEAT PUMP
  - WIDE HEAT LOAD RANGE CAPABILITY
  - LOW DOLLARS/KW OF HEAT REJECTION

TECHNOLOGY DEVELOPMENT REQUIREMENTS AND ISSUES

- LONG LIFE THERMAL SYSTEMS
  - MINIMUM COMPLEXITY
  - TRANSPORT SYSTEM FLUID COMPATIBILITY AND HIGH/LOW TEMP. MATERIALS
  - MICROMETEOROID COUNTERMEASURES - INTEGRAL SPACECRAFT RADIATORS
  - COMPATIBILITY WITH SPACE PLASMA ENVIRONMENT AND NATURAL RADIATION
  - MAINTAINABILITY VS LONG-LIFE TRADEOFFS
- THERMAL SYSTEMS
  - SYSTEM INTEGRATION WITH POWER GENERATION, DISTRIBUTION, AND STORAGE
  - AUTOMATIC CONTROL - MICROPROCESSOR
  - SUBSYSTEM INTERFACE/INTERACTION
  - COMPONENT/SUBSYSTEM SIMULATION AND DEMONSTRATION TESTS

100 KW THERMAL UTILITY SYSTEM



THERMAL UTILITY SYSTEM FOR HIGH POWER SPACE PLATFORMS

OBJECTIVES

- DEVELOP THE COMMENSURATE TECHNOLOGIES NECESSARY FOR THERMAL MANAGEMENT, THERMAL ACQUISITION AND TRANSPORT, AND HEAT REJECTION FOR LARGE POWER (>100KW) SPACE PLATFORM SYSTEMS
- PROVIDE A 1987 TECHNOLOGY READINESS FOR A PLATFORM THERMAL UTILITY SYSTEM, INTEGRAL TO SPACE PLATFORM AND INSENSITIVE TO MULTIDISCIPLINARY USER LOADS
- REDUCE COMPONENT AND SUBSYSTEM LIFE-CYCLE COSTS AND PROVIDE ECONOMICAL BASIS FOR AN EFFICIENT POWER-THERMAL SYSTEM

THERMAL UTILITY SYSTEM FOR HIGH POWER SPACE PLATFORMS

Working Group Top (#1) Priority Assessment

TASK #	TECHNOLOGY ISSUE	Center	FY 1980	FY 1981	FY 1982
	Thermal Management				
1.	Conduct system analysis of thermal management system requirements for a large capacity, high voltage utility service.	LeRC	60	75	-
5.	Analyze centralized thermal utility potential for thermal control of multi-discipline instruments with varying requirements.	GSFC	25	-	-
6.	Scope the platform thermal distortion interactions with instrument and subsystem stability requirements.	GSFC	25	LSST	-
9.	Investigate the redundancy and fail safe approaches to achieve reliability in thermal systems integration.	MSFC	-	20	50
10.	Develop efficient centralized thermal transport and temperature control scheme, i.e., collection and rejection, over wide band of heat loads.	JSC	75	100	150
12.	Improve science/application instrumentation temperature control schemes.	GSFC	75	90	125
13.	Investigate the impact on system thermal design factors imposed by military high reliability-survivability requirements, e.g., laser hardening, deployable-retractable radiators, etc.	AFWAL	-	50	50
24.	Study integration schemes for waste heat utilization prior to radiator rejection.	LeRC	-	40	-
46.	Study the conflicting relationship of incorporating an "up-front" thermal management system design with the expected step-wise growth of orbital power systems.	MSFC	-	20	50
	Thermal Acquisition & Transport				
18.	Develop and test physical heat transport system interfaces for thermal umbilical, fluid/heat pipe disconnects, gimbal joints, flex joints, contact heat exchanger, etc. components.	MSFC JSC	125	150	300
19.	Identify thermal interface concepts for instruments/ support structures integration into centralized thermal transport system.	GSFC MSFC	60	80	-
20.	Explore new heat pipe designs to permit high heat transport that minimizes impact on heat transfer efficiency.	JSC	100	150	175
16.	Study contamination, surface charging and degradation effects on thermal control surfaces.	GSFC MSFC	50	80	100
29.	Develop high thermal conductivity materials for thermal joint interfaces.	LeRC	LSST	LSST	LSST

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Working Group Top (#1) Priority Assessment

TASK #	TECHNOLOGY ISSUE	Center	FY 1980	FY 1981	FY 1982
Thermal Acquisition & Transport (Continued)					
32.	Analyze and define thermal buss concepts.	JSC	50	90	160
53.	Explore application of heat pipes and solid thermal conductors integral to instrumentation and power equipment.	LeRC GSFC MSFC	60	100	-
Heat Rejection					
37.	Demonstrate heat rejection limits to extend length heat pipe concepts.	JSC MSFC	50	100	175
38.	Survey and select competing heat pipe design concepts for breadboard development, e.g., osmetic, etc.	GSFC	50	100	100
39.	Conduct parametric scaling optimization analyses for high power heat pipe rejection concepts.	JSC	25	-	-
40.	Demonstrate the heat pipe radiator interface performance with thermal transport schemes.	JSC	-	50	100
Life Cycle Costs					
42.	Analyze the "long-life" requirement in thermal components and subsystems against replacement, modular assembly and maintainability tradeoffs.	MSFC JSC LeRC GSFC	20	20	75
44.	Prioritize low-cost driver technologies in thermal control.	JSC GSFC LeRC MSFC	10	30	50
		Total	860	1345	1610

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Working Group High (#2) Priority Assessment

TASK #	TECHNOLOGY ISSUE	Center	FY 1982	FY 1983	FY 1984	FY 1985
	Thermal Management					
2.	Define a representative thermal load utility profile for a broad range of user and operational requirements.	LeRC	50	25	-	-
4.	Define the interaction of the spacecraft charge environment with thermal control contamination.	GSFC LeRC AFWAL	40	60	90	40
11.	Investigate induced contamination environment effects on power-thermal surfaces.	GSFC	50	50	50	50
51.	Investigate the timing extent of prototype and large ground test verification at the system and subsystem level.	MSFC JSC	100	100	75	75
47.	Conduct modeling and analysis of thermal system performance and operating characterization.	LeRC JSC	80	100	100	200
	Thermal Acquisition and Transport					
15.	Investigate thermal system sensitivity parameters to instrument and subsystem changeouts.	GSFC JSC	50	75	100	-
48.	Investigate thermal system interfaces (e.g. cold plates) with highly concentrated thermal loads from high watt density devices and HV power modules.	GSFC MSFC AFWAL	100	100	100	-
17.	Investigate alternative fluids utilization and identify tradeoff options.	LeRC GSFC	100	150	100	50
22.	Study the thermal control tradeoffs of inductive power transfer versus HVDC.	LeRC	50	-	-	-
23.	Investigate large scale thermal storage devices for heat load leveling and large thermal transients.	LeRC MSFC AFWAL	150	100	100	50
27.	Explore polymeric and flexible heat pipe utilization in thermal connectors.	LeRC	100	-	100	-
30.	Evaluate system capabilities of a representative thermal transport concept employing fluid loops, heat pipes and controlled heat conduction umbilical.	LeRC JSC	300	400	300	200
	Heat Rejection					
33.	Explore centralized and decentralized systems of heat rejection, e.g., heat pipe radiators integral to spacecraft hull and deployable/retractable radiators.	JSC AFWAL	80	80	80	-
49.	Define the potential and application of advanced heat pipes, e.g. osmotic, ion-drag, etc.	GSFC LeRC	100	100	100	100
	Total, $K	XX	1350	1340	1295	765

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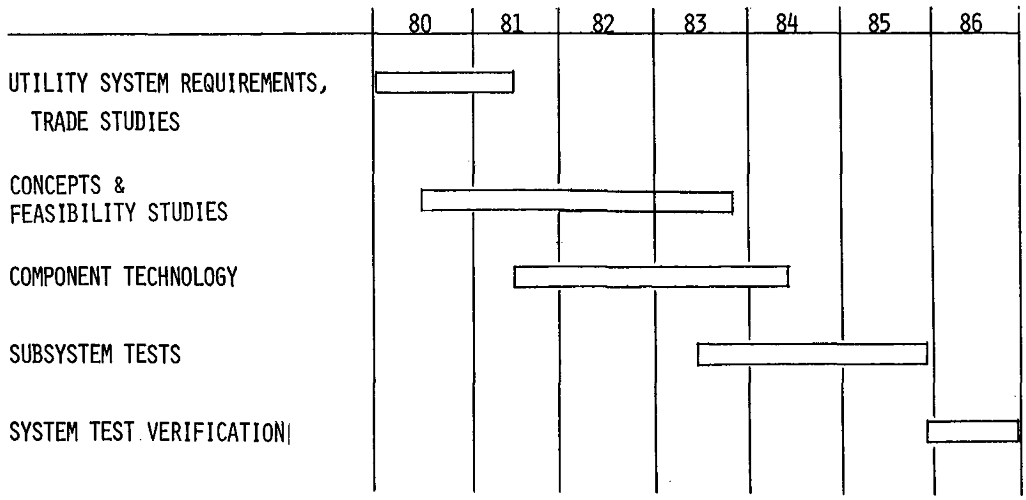
Working Group Deferred Start (#3) Priority Assessment

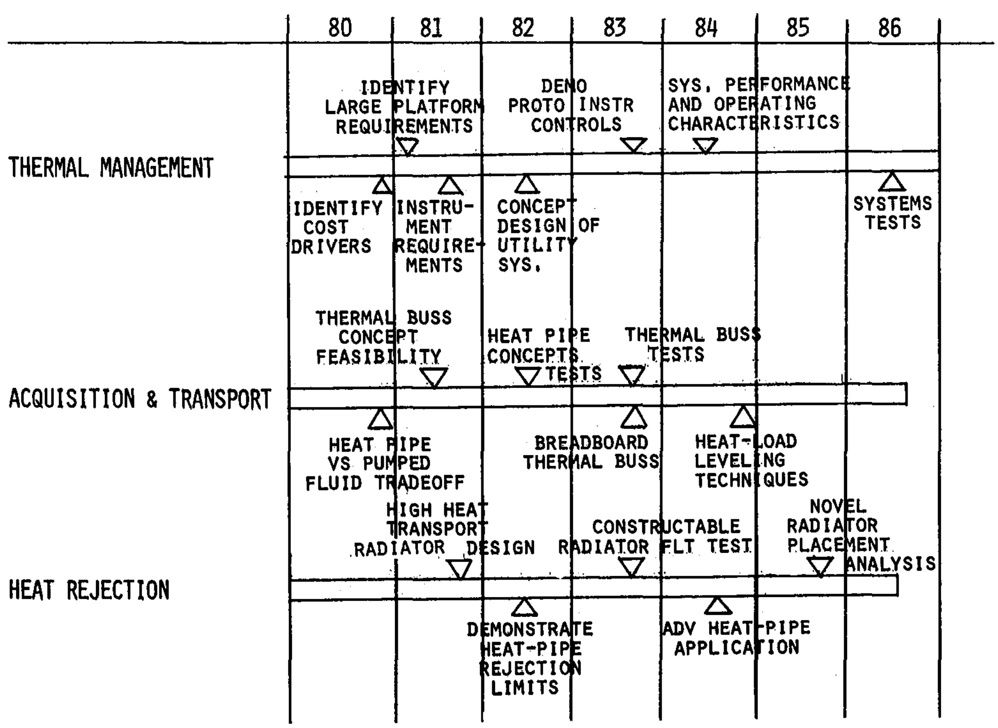
TASK #	TECHNOLOGY ISSUE	Center	FY 1983	FY 1984	FY 1985	FY 1986
Thermal Management						
3.	Study the integration of thermal control electronics, e.g. sensors and micro-processors with power processing electronics.	MSFC LeRC GSFC	150	100	200	200
8.	Do life support system requirements impose unique thermal management constraints?	JSC	50	50	-	-
14.	Develop thermal radiation environment and thermal analyzer analytical tools for design and verification of large power-thermal systems.	JSC	180	300	300	100
Thermal Acquisition and Transport						
26.	Explore techniques for structure heat path utilization, e.g. controlled heat leaks to outer spacecraft hull.	LaRC GSFC MSFC	150	100	50	50
Heat Rejection						
34.	Analyze thermal radiation environments in novel radiator placement locations.	JSC	75	100	100	-
35.	Study heat rejection integration with higher efficiency regenerative fuel cell-electrolysis energy storage systems.	JSC LeRC	100	100	-	-
36.	Analyze special purpose power reserves where exotic battery concepts, e.g. Na and Li, may introduce significant thermal control gradients compared to NiH_2 approaches.	MSFC JSC LeRC	125	100	75	-
41.	Study GaAs concentrator or other high temperature array concepts (e.g. thermal-voltaic and spectrophotovoltaic convertors) require different approaches in heat dissipation.	MSFC	200	200	100	100
	TOTAL, $K	XX	1080	1050	825	450

THERMAL MANAGEMENT



THERMAL MANAGEMENT

(MILESTONE SCHEDULES)



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RESOURCE 1987 TECHNOLOGY READINESS SCHEDULE, $K (FY '80$)

	# TASKS	FY '79	FY '80	FY '81	FY '82	FY '83	FY '84	FY '85	FY '86	TOTALS
THERMAL MANAGEMENT										4297
Priority #1	11	47	290	445	550					
Priority #2	5				320	335	315	365		
Priority #3	3					380	450	500	300	
THERMAL ACQUISITION & TRANSPORT										5030
Priority #1	7	75	445	650	735					
Priority #2	7				850	825	800	300		
Priority #3	1					150	100	50	50	
HEAT REJECTION										2815
Priority #1	4		125	250	375					
Priority #2	2				180	180	180	100		
Priority #3	4					550	500	275	100	
	TOTAL	122	860	1345	3010	2420	2345	1590	450	12142

THERMAL MANAGEMENT
(MAJOR CENTER EFFORTS)

JSC

- DEVELOP THERMAL TRANSPORT AND TEMPERATURE CONTROL SCHEMES
- THERMAL BUSS
- HEAT REJECTION CONCEPTS ANALYSIS
- RADIATORS CONCEPTS; DEPLOYABLE, CONSTRUCTABLE

LERC

- THERMAL SYSTEM REQUIREMENTS FOR LARGE PLATFORMS
- THERMAL CONTROL TRADEOFFS
- WASTE HEAT UTILIZATION
- HIGH THERMAL CONDUCTIVITY MATERIALS

GSFC

- COOLING AND CONTROL OF MULTI-DISCIPLINE INSTRUMENTS
- THERMAL INTERFACE CONCEPTS FOR INSTRUMENTS
- HEAT-PIPE DESIGN CONCEPTS

MSFC

- THERMAL CONTROL SURFACES
- THERMAL SYSTEMS INTEGRATION
- TRANSPORT SYSTEM INTERFACES

FY 1980 THERMAL MANAGEMENT PROGRAM

JSC: 300K

- o HEAT PIPE FEASIBILITY DEMONSTRATION
- o BEGIN RADIATOR SYSTEM DESIGN
- o IDENTIFICATION OF THERMAL BUSS REQUIREMENTS & CONCEPT DEFINITION
- o IDENTIFICATION OF INTERFACE REQUIREMENTS

MSFC: 60K

- o THERMAL CONTROL COATINGS

LERC: 120K

- o CONTINUE VOUGHT STUDY (UNMANNED MODULE PROBLEMS, INTEGRATION PROBLEMS WITH THERMAL BUSS CONCEPT)
- o PRELIMINARY EFFORTS FOR MEASUREMENT OF HIGH PERFORMANCE SOLID THERMAL CONDUCTORS

GSFC: 120K

- o IDENTIFY INSTRUMENT THERMAL CONTROL REQUIREMENTS & INSTRUMENT TECHNOLOGIES
- o SELECTION OF HEAT TRANSFER DEVICES FOR BREADBOARD DEVELOPMENT

THERMAL MANAGEMENT SYSTEM BENEFITS

- o IMPROVE BASIS FOR SCALE-UP TO VERY LARGE POWER SYSTEMS
- o PROVIDE COMMENSURATE DATA BASE IN THERMAL UTILITY DESIGN OPTIONS FOR LARGE CAPACITY, HIGH VOLTAGE POWER GENERATION AND STORAGE CAPABILITIES
- o REDUCED RISK BY EXPANDING EXPERIENCE/DATA BASE IN LONG-LIFE AND HIGH TEMPERATURE COMPONENTS AND MINIMIZING SYSTEM DESIGN COMPLEXITY
- o REDUCED DEVELOPMENT COSTS THROUGH MODULARITY, SYSTEMS LEVEL DESIGN APPROACH, INTEGRATION WITH OTHER SUBSYSTEMS, REDUCED WEIGHT AND VOLUME
- o IMPROVED UTILIZATION OF ORBITER AND SHUTTLE CAPABILITIES
- o EXTENDED LIFETIME THROUGH MAINTAINABILITY/REPLACEABILITY, MATERIALS COMPATIBILITY, AND REDUCED ADVERSE ENVIRONMENTAL INTERACTIONS
- o REDUCED OPERATIONAL AND PAYLOAD INTEGRATION COSTS WITH CENTRALIZED POWER-THERMAL SYSTEM
- o REDUCED COSTS FOR ALL USERS THROUGH INSTRUMENT THERMAL DESIGN IMPROVEMENTS AND CENTRALIZED THERMAL UTILITY