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VOYAGER SPACECRAFT

Study
under NAS 7-100

AUGUST 11 1965

TRW SYSTEMS

STUDY SCOPE

BASIC REQUIREMENTS

- SPACECRAFT ADAPTABLE TO VARIETY OF CAPSULE AND SCIENCE PAYLOAD DESIGNS
- SIMPLE AND CONSERVATIVE DESIGN
- DEVIATIONS FROM SPECIFIED CONSTRAINTS ONLY IF FULLY JUSTIFIED
- COMPLETE STUDY IN 13 WEEKS

APPROACH

- ANALYZE MAXIMUM NUMBER OF ALTERNATIVES AND JUSTIFY TRADEOFF DECISIONS
- DETAILED DESIGN FOR SELECTED SPACECRAFT
- DETAILED DESIGN FOR 1969 TEST SPACECRAFT, DUPLICATING 1971 DESIGN INsofar AS POSSIBLE

GENERAL STUDY PROBLEMS

DEFINITION OF SCIENCE PAYLOAD

ALLOWABLE DYNAMIC ENVELOPE

MAKING DESIGN SELECTIONS

TECHNICAL DESIGN PROBLEMS

1969 TEST FLIGHT

DEFINITION OF SCIENCE PAYLOAD

AFFECTED:

MOUNTING PROVISIONS AND FIELDS OF VIEW FOR
BODY-MOUNTED EXPERIMENTS

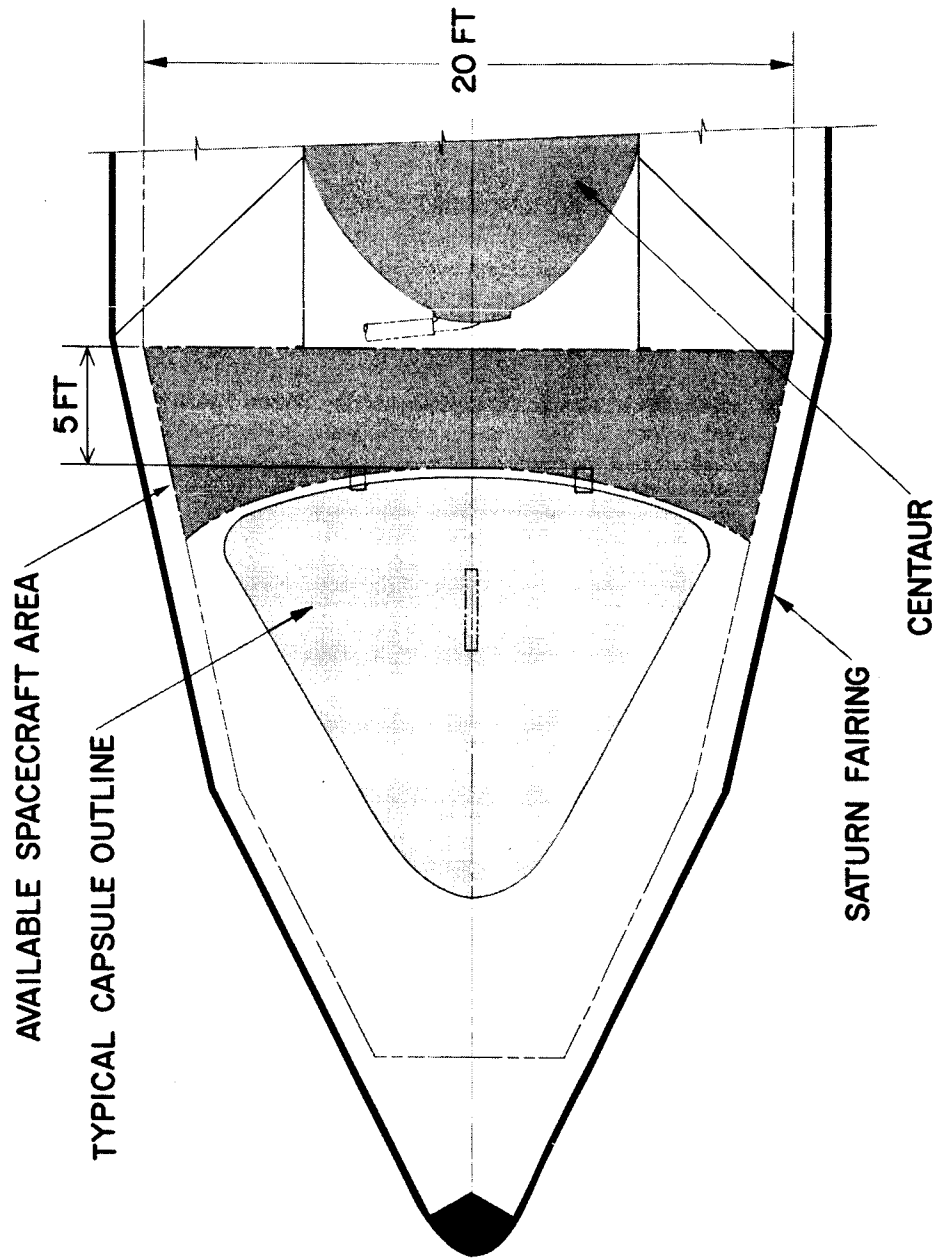
SIZE, INERTIAS, THERMAL CONTROL, VIEWING ANGLES,
AND POINTING ACCURACY FOR POP

AND PLACED CONSTRAINTS ON:

SPACECRAFT MAGNETIC CLEANLINESS

TELEMETRY DATA RATE

SPECIFIED ENVELOPE FOR VOYAGER PLANETARY VEHICLE



MAKING DESIGN SELECTIONS

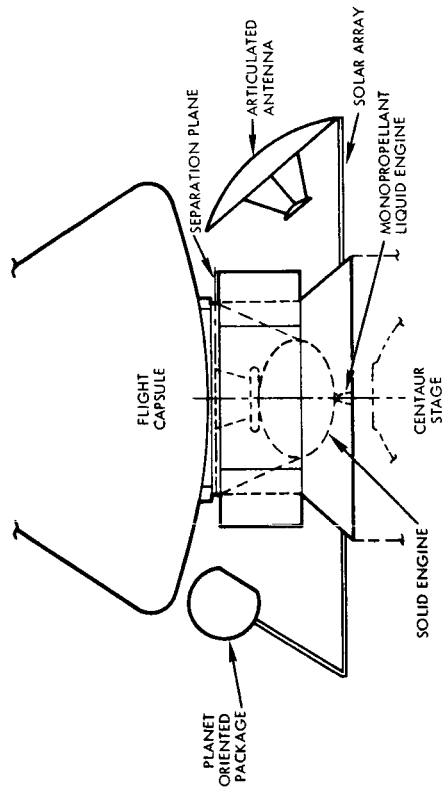
REQUIRED:

JUDGMENT ON WEIGHTING DESIGN CRITERIA

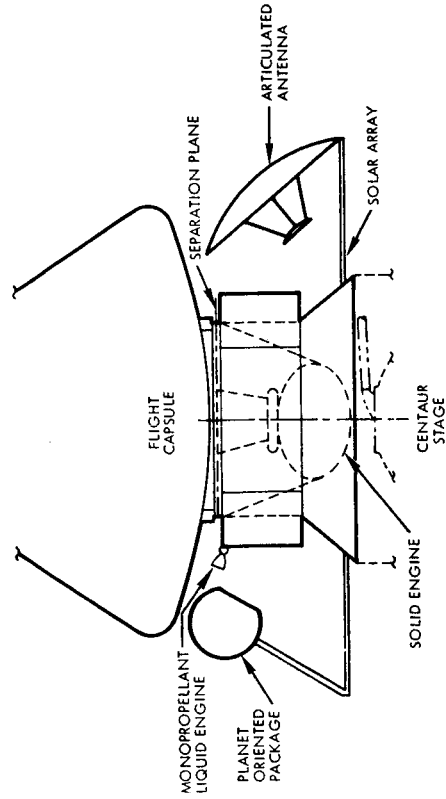
CHOICE OF CONFIGURATIONS TO RETAIN

**METHODOLOGY FOR EVALUATING ALTERNATE
CONFIGURATIONS**

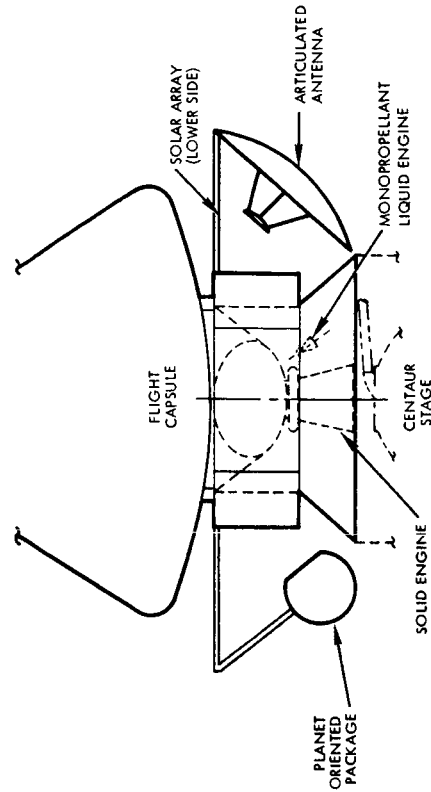
ALTERNATE PROPULSION ARRANGEMENTS FOR CONFIGURATION A



ALTERNATE 1
(SELECTED AS CONFIGURATION A)



ALTERNATE 2

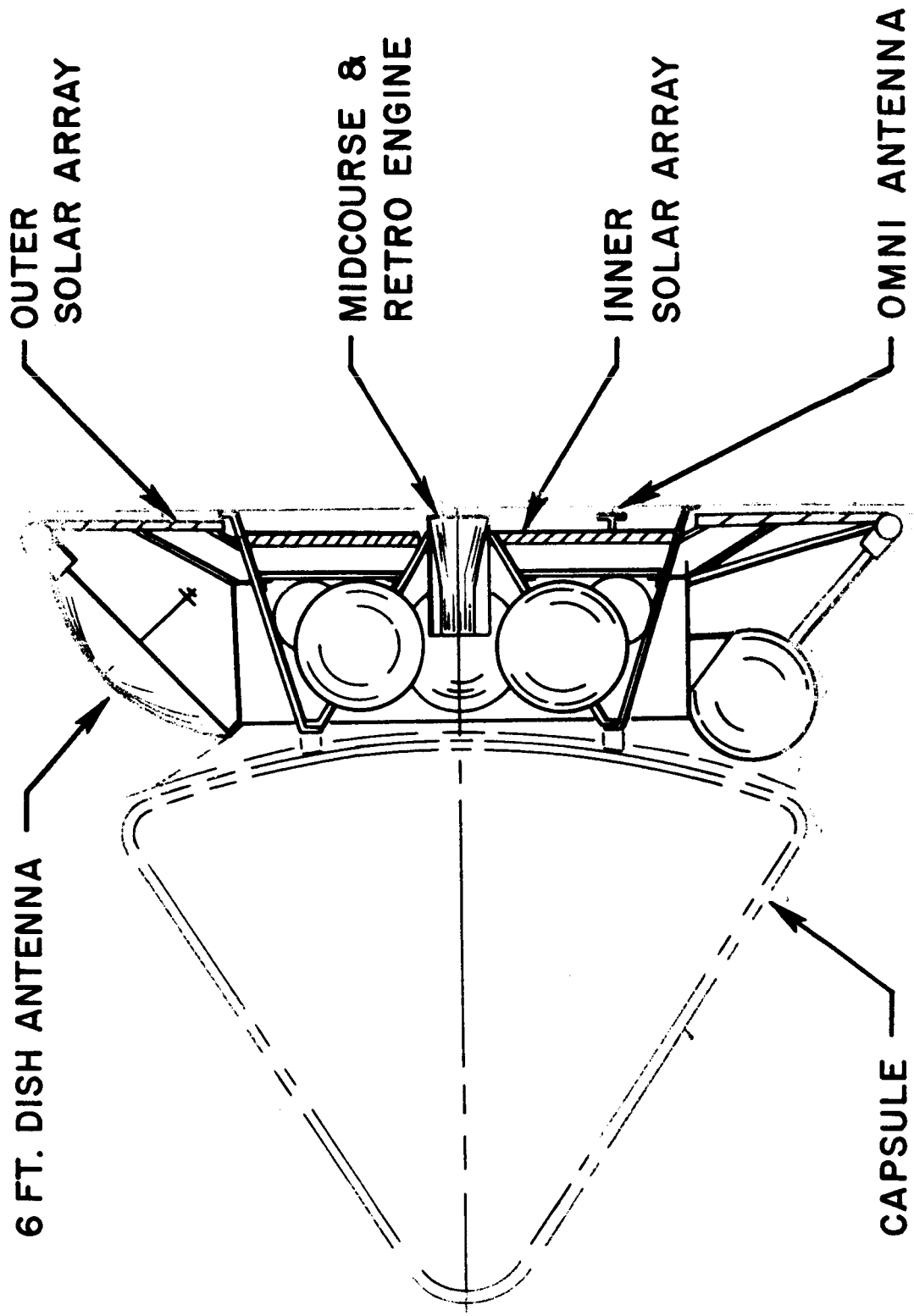


ALTERNATE 3

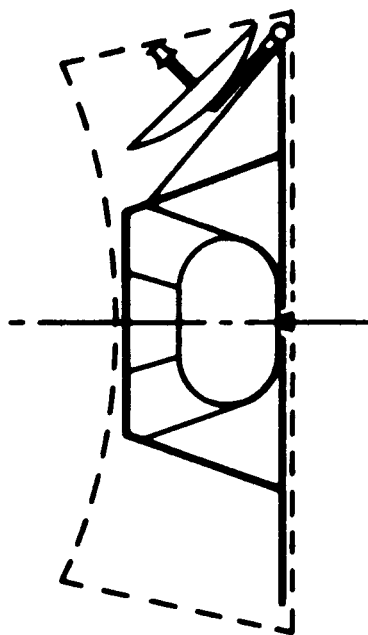
COMPARISON OF SOLID ENGINE ALTERNATES

	ALTERNATE 1	ALTERNATE 2	ALTERNATE 3
● SEPARATIONS TO CLEAR NOZZLE	ONE	ONE	ONE
● MIDCOURSE THRUST AXIS	ON CENTERLINE	NEARLY LATERAL	OFF CENTERLINE
● SOLAR ARRAY AREA	20% MORE AREA THAN NO. 3	20% MORE AREA THAN NO. 3	SMALLEST
● ANTENNA DIAMETER	5 FT	5 FT	5 FT
● ANTENNA LOOK ANGLES	LEAST RESTRICTED	LEAST RESTRICTED	MOST RESTRICTED
● SOLAR CELL CONTAMINATION	VERY LOW	VERY LOW	GREATEST
● PROPULSION PACKAGE MODULARITY	LEAST	LEAST	INTERMEDIATE
● SPACE FOR SOLID ENGINE	LEAST	SMALLEST	GREATEST
● REFLECTED SUNLIGHT ON LOUVERS			GREATEST

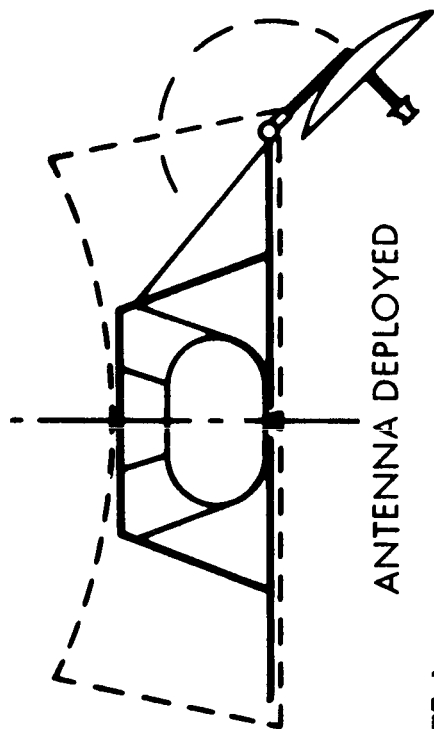
CONFIGURATION B: BIPROPELLANT LIQUID PROPULSION



ANTENNA SIZE EVOLUTION

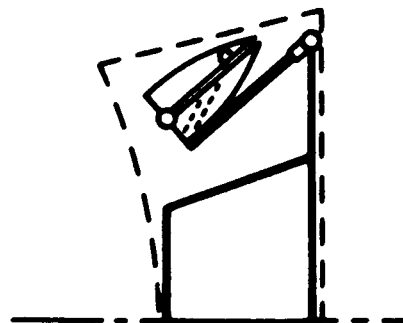


ANTENNA STOWED

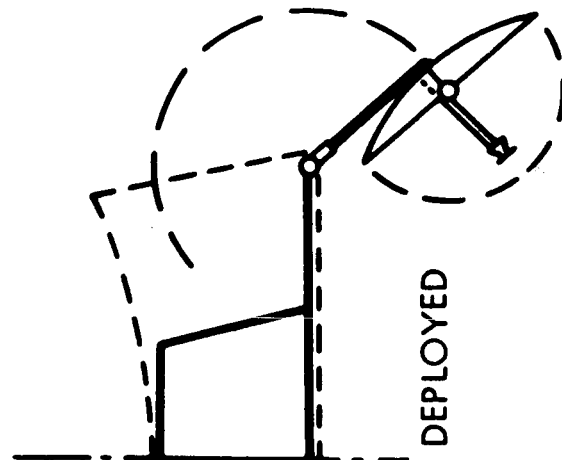


ANTENNA DEPLOYED

ALTERNATE 1
(CONFIGURATION A)



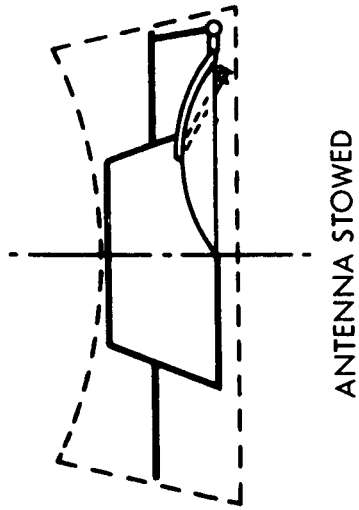
ANTENNA STOWED



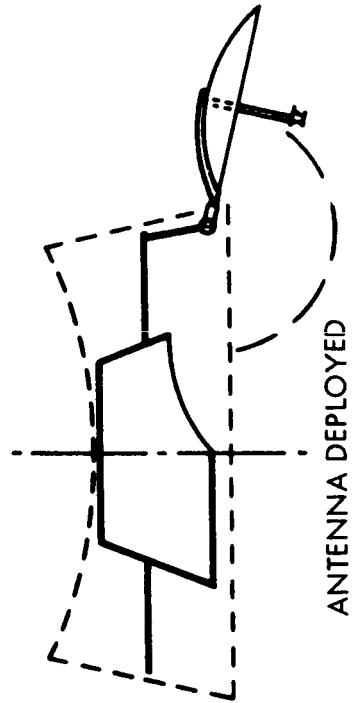
ANTENNA DEPLOYED

ALTERNATE 2

ANTENNA SIZE EVOLUTION

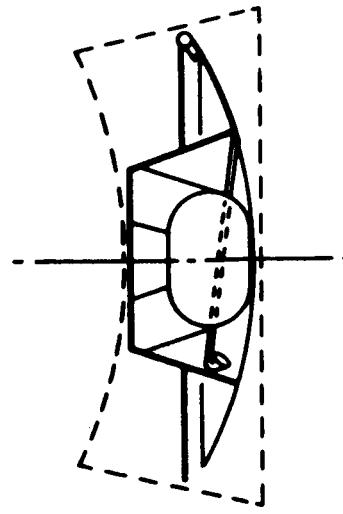


ANTENNA STOWED

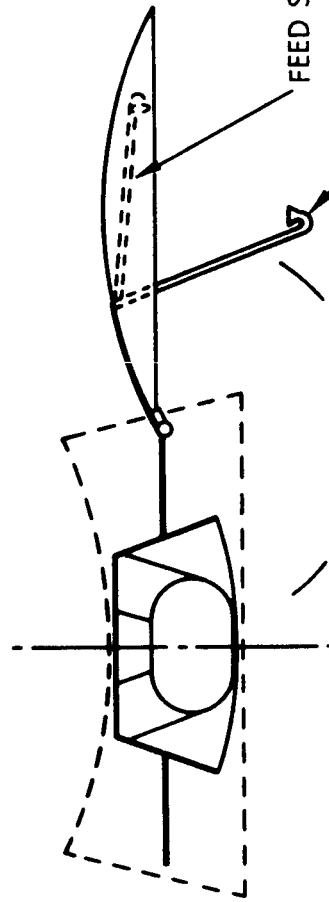


ANTENNA DEPLOYED

ALTERNATE 3



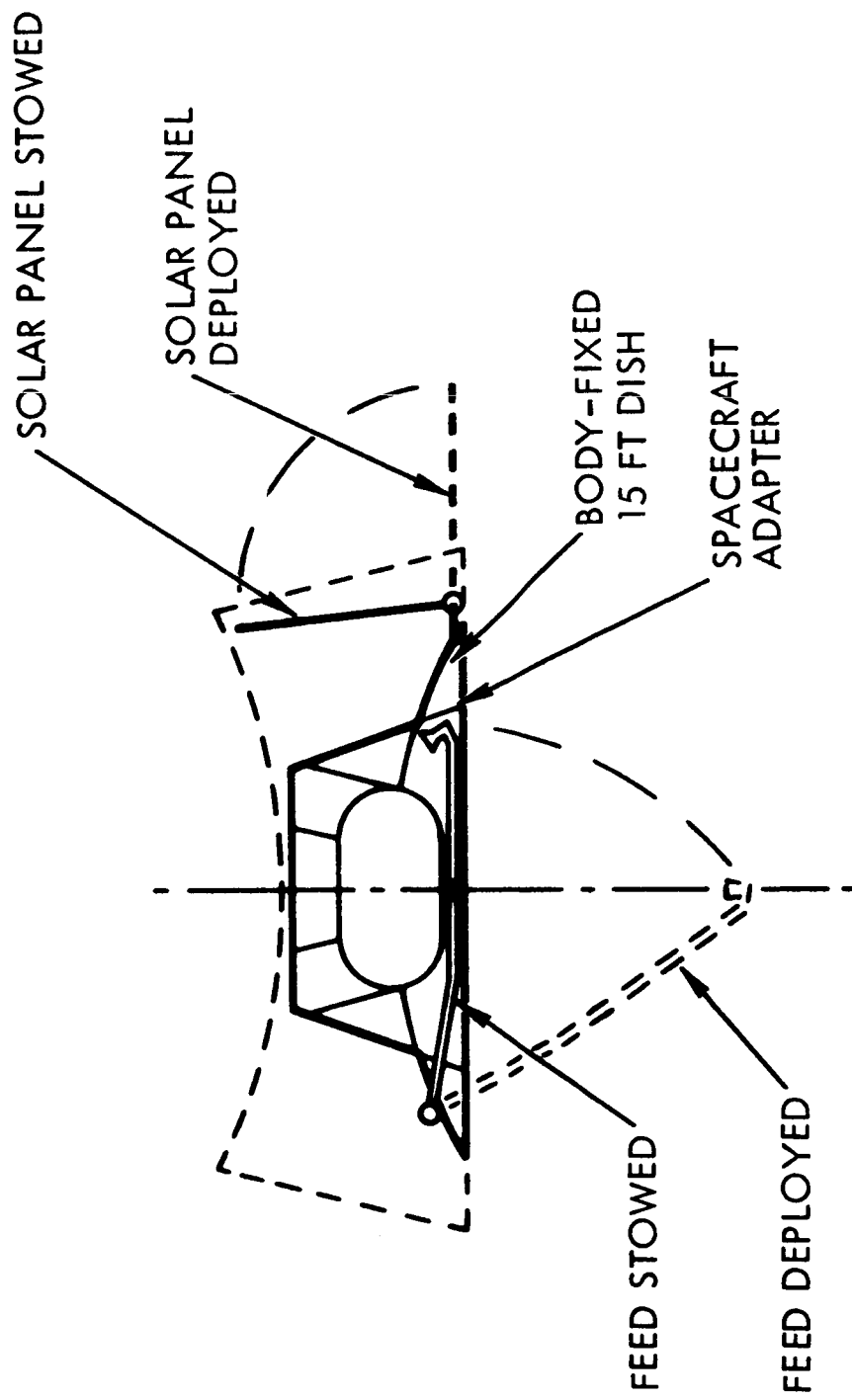
ANTENNA STOWED



ANTENNA DEPLOYED

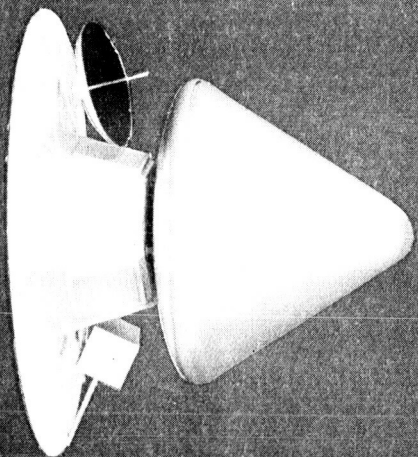
ALTERNATE 4

ANTENNA SIZE EVOLUTION

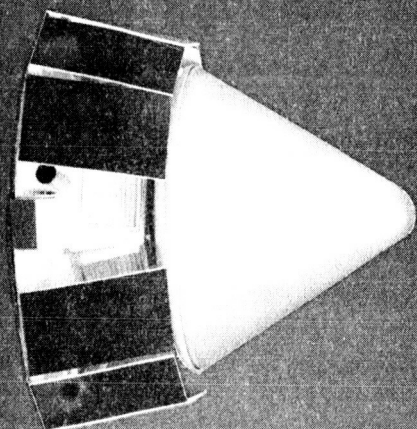


**ALTERNATE 5
(CONFIGURATION C)**

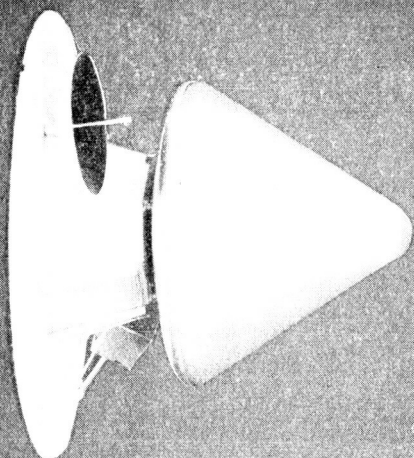
MODELS OF THREE BASELINE CONFIGURATIONS



A



C



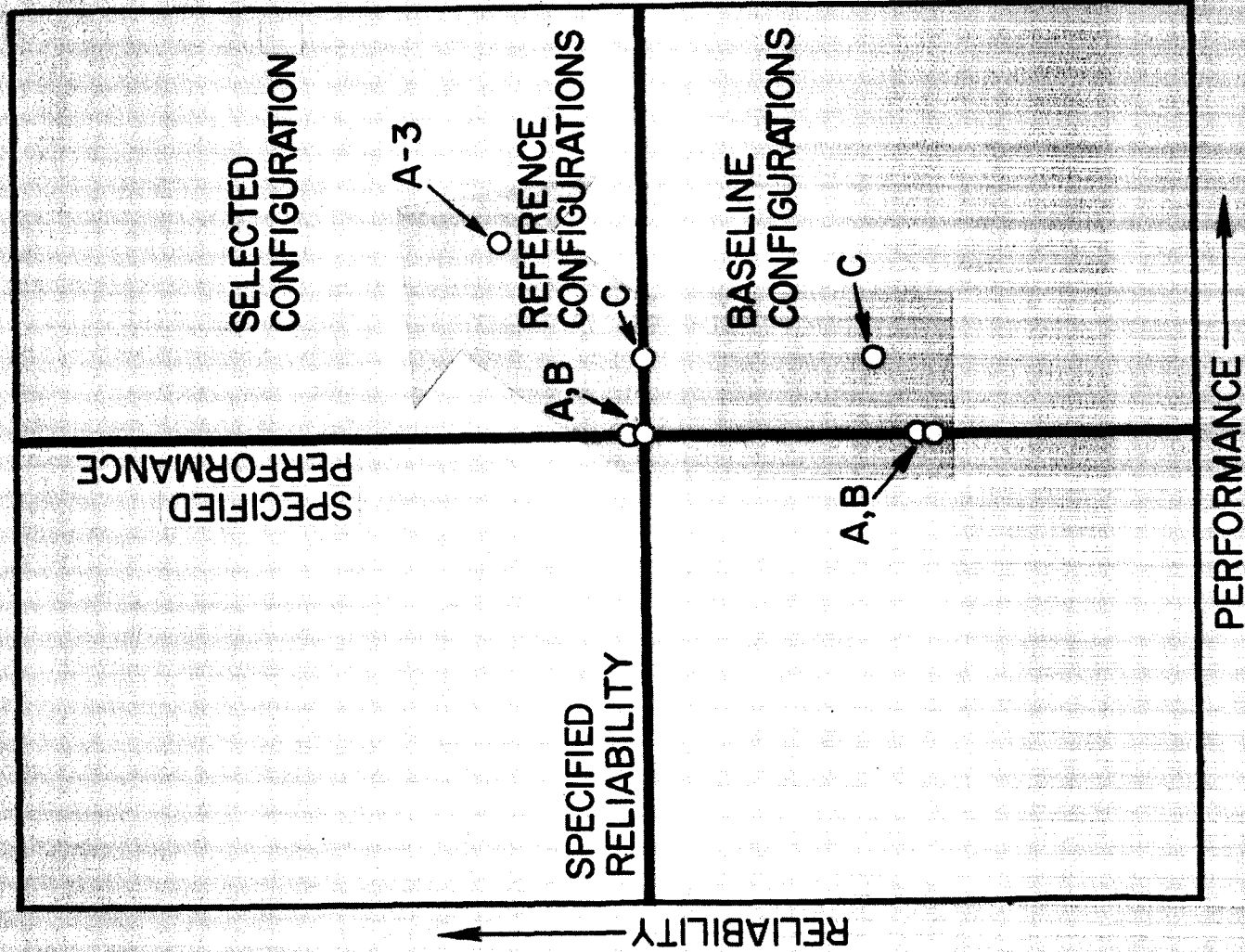
B

MAKING DESIGN SELECTIONS

REQUIRED:

- **JUDGMENT ON WEIGHTING DESIGN CRITERIA**
- **CHOICE OF CONFIGURATIONS TO RETAIN**
- **METHODOLOGY FOR EVALUATING ALTERNATE CONFIGURATIONS**

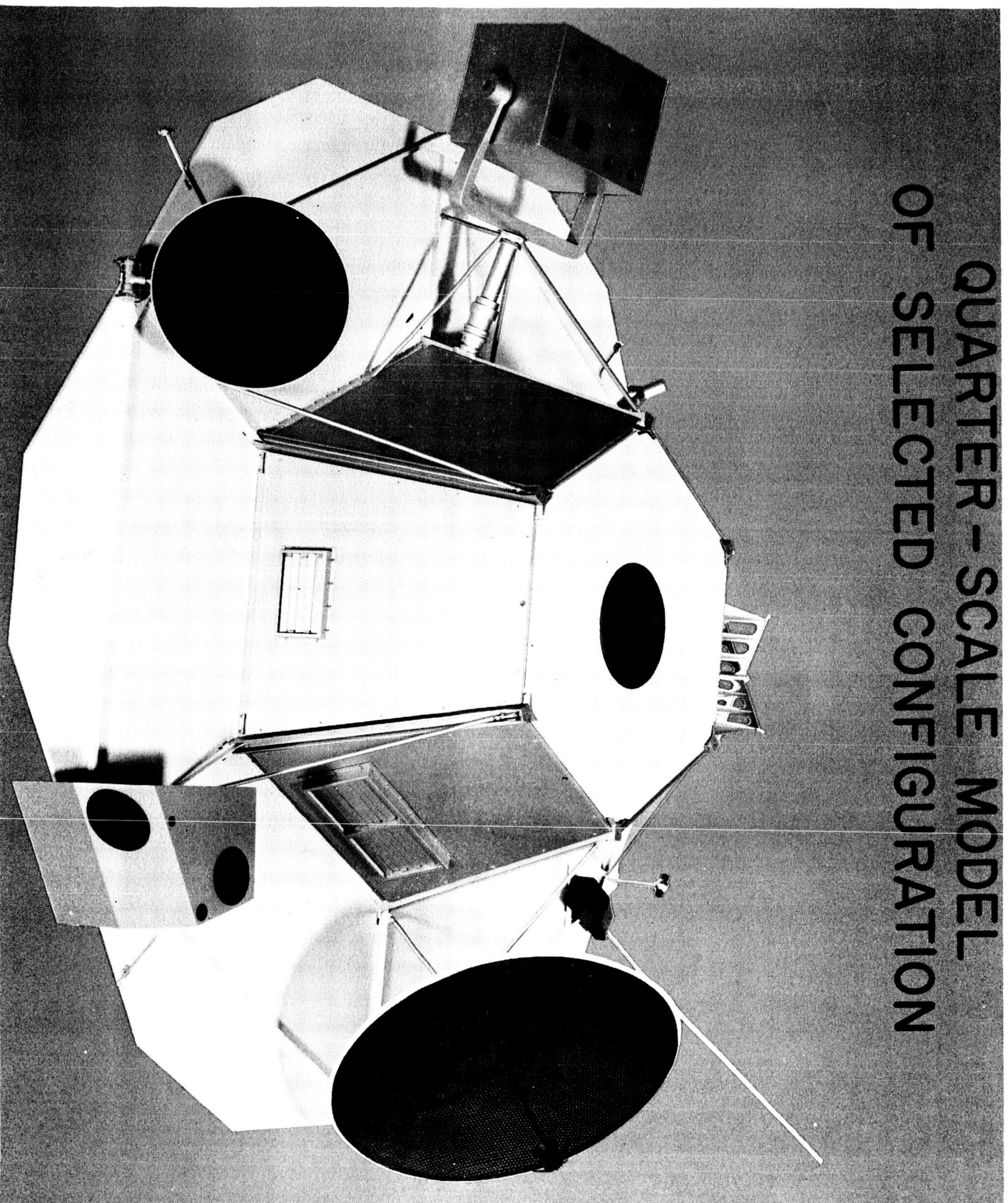
SPACECRAFT CONFIGURATION EVOLUTION



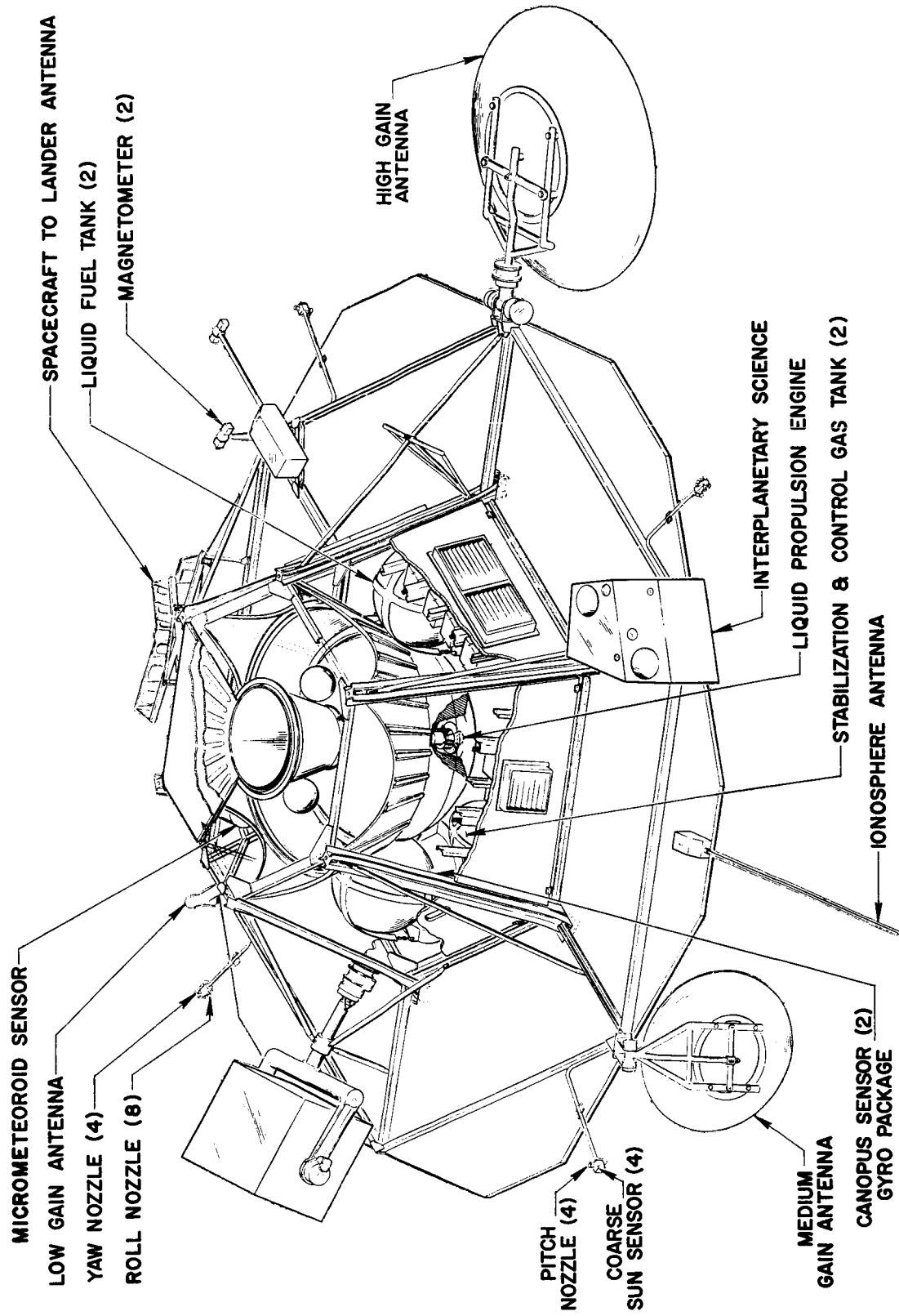
KEY COMPARISONS OF CONFIGURATIONS A AND C

FUNCTIONAL AND DESIGN FACTORS	CONF. A 6-FT GIMBALLED ANTENNA	CONF. C 16-FT FIXED ANTENNA
<u>COMMUNICATIONS AND CS & C:</u>		
● MAX. DATA RATE	4096 BITS/SEC	~29,000 BITS/SEC
● DATA ACQUISITION, STORAGE AND TELEMETRY	SIMPLER	GREATER TAPE STORAGE CAPACITY NEEDED; MORE COMPLEX
<u>STABILIZATION AND CONTROL:</u>		
● ANTENNA POINTING ACCURACY REQUIRED	~1 DEGREE	~0.3 DEGREE: REQUIRES TIGHTER LIMIT CYCLE
● ACQUISITION OF CELESTIAL REFERENCES	SIMPLER	MORE COMPLEX SEQUENCE
● SENSORS	FEWER IN-LINE SENSORS	NEEDS EARTH SENSOR
<u>GENERAL DESIGN FACTORS:</u>		
● ARTICULATED SUBSYSTEMS	MORE GIMBALS	ADAPTABLE TO SINGLE - GIMBAL POP
● SOLAR CELL PANELS	FIXED	DEPLOYABLE
● DESIGN AND OPERATION CONSERVATISM		LESS CONSERVATIVE

QUARTER-SCALE MODEL OF SELECTED CONFIGURATION



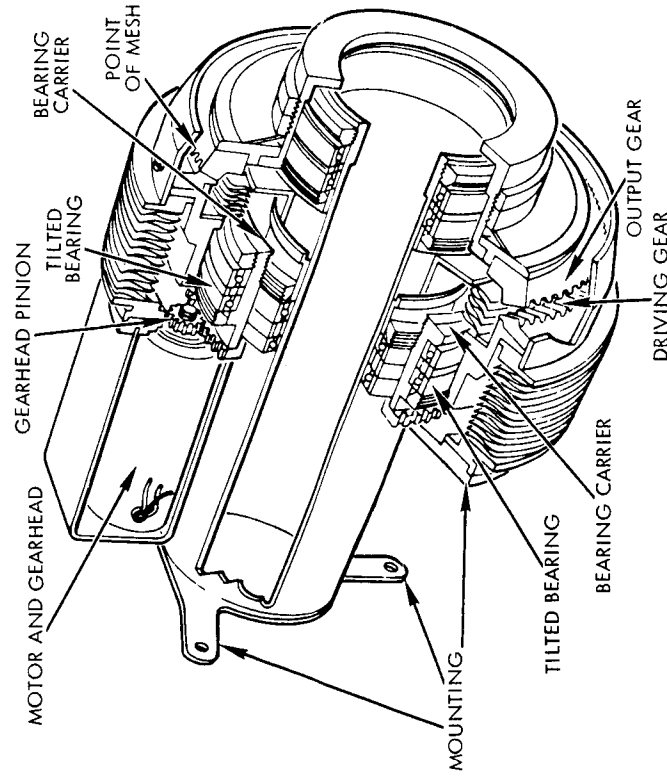
1971 VOYAGER SPACECRAFT ISOMETRIC VIEW



TECHNICAL PROBLEMS

- POP DRIVE AND SCANNING
- CAPSULE INTERFACE
- ECLIPSE SURVIVAL
- CENTRAL SEQUENCER AND COMMAND REQUIREMENTS
- CONTAMINATION AVOIDANCE
- PROPULSION CHOICE
- COMMUNICATIONS PERFORMANCE
- ▲ SIMPLICITY AND FLEXIBILITY
- ▲ RELIABILITY ACHIEVEMENT

WABBLE GEAR DRIVE



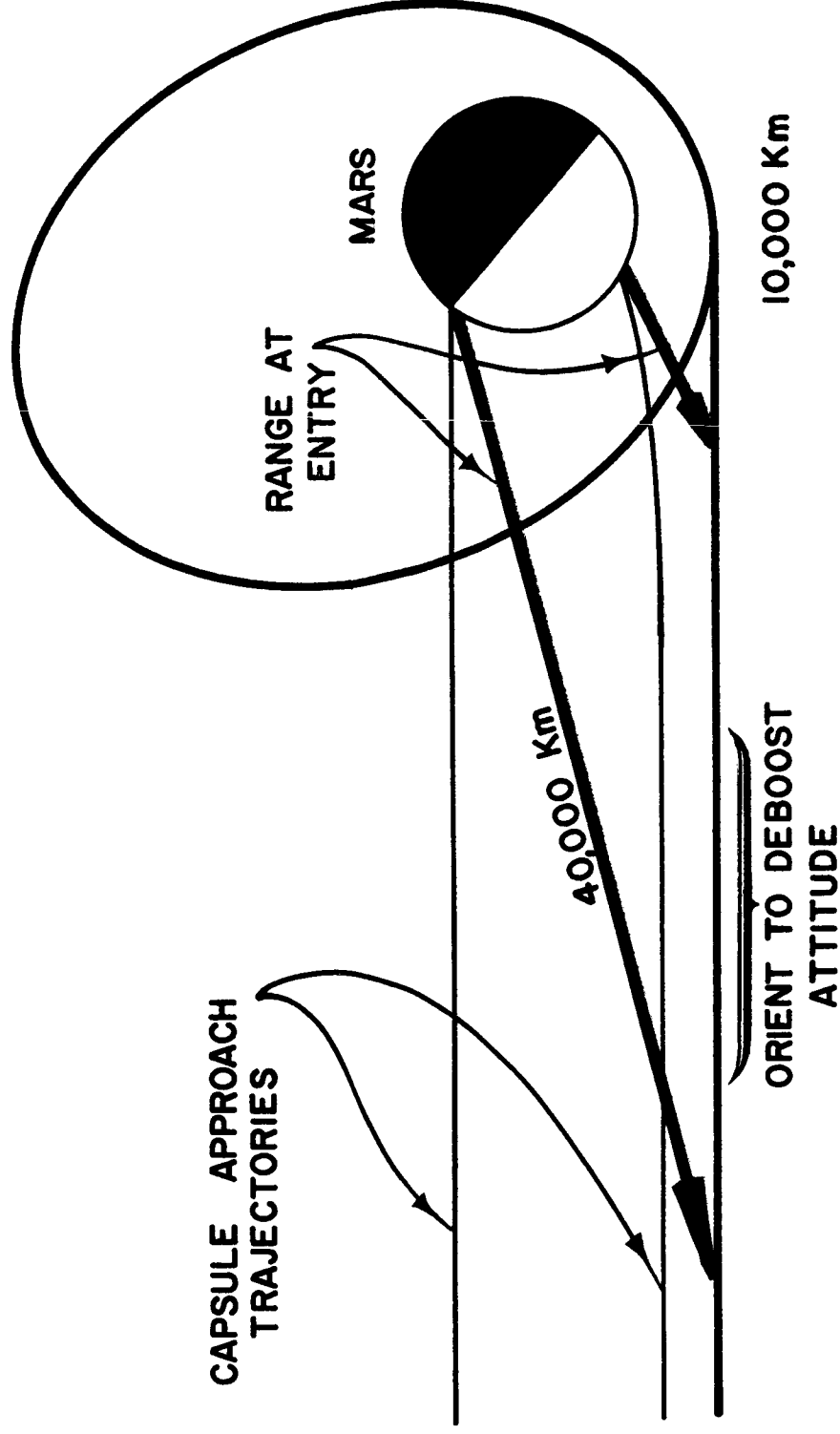
OGO EXPERIENCE

SOLAR CELL PADDLE SHAFT
ORBIT PLANE EXPERIMENT SHAFT

BOTH GEARS HAVE OPERATED
SUCCESSFULLY SINCE SEPTEMBER
1964 LAUNCH: DUTY CYCLE OF
ABOUT 10-MIN OPERATION ONCE
A MONTH

OVER ONE YEAR LIFE TEST IN VACUUM

ALTERNATE SEQUENCES AT ENCOUNTER



TECHNICAL PROBLEMS

- **POP DRIVE AND SCANNING**
- **CAPSULE INTERFACE**
- **ECLIPSE SURVIVAL**
- **CENTRAL SEQUENCER AND COMMAND REQUIREMENTS**
- **CONTAMINATION AVOIDANCE**
- **PROPULSION CHOICE**
- **COMMUNICATIONS PERFORMANCE**
- ▲ **SIMPLICITY AND FLEXIBILITY**
- ▲ **RELIABILITY ACHIEVEMENT**

**EXAMPLE OF DESIGN APPROACH :
SPACECRAFT-EARTH COMMUNICATIONS LINK**

BASELINE REQUIREMENTS

ESTABLISHMENT OF BASELINE SYSTEM

RELIABILITY IMPROVEMENT

FUNCTIONAL REDUNDANCY

EQUIPMENT REDUNDANCY

DATA REQUIREMENTS AND CAPABILITY

REQUIREMENTS

CAPABILITY

70% OF MARS = 10^8 KM²

1-KM RESOLUTION
(2.8 LINES / KM)

6-BIT GRAY LEVEL

0.5×10^{10} BITS

100% OVERLAP IN
ALTERNATE COLOR

0.5×10^{10} BITS

EQUAL DATA AT
50-M RESOLUTION

1.0×10^{10} BITS

1300 BITS / SEC OVER 6 MONTHS

6-FT ANTENNA

20-W TWT

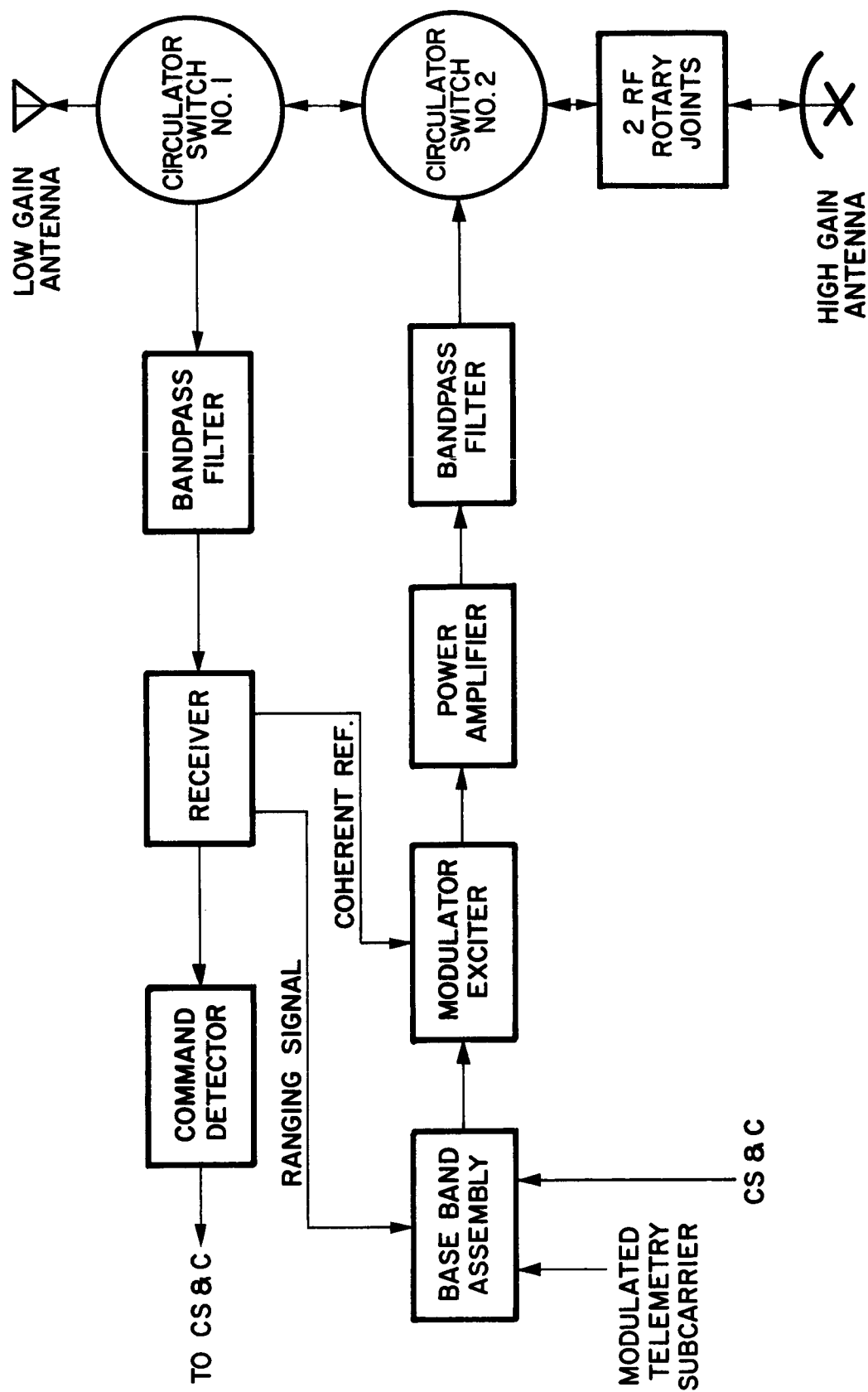
4096 BITS/SEC AT
ENCOUNTER + 2 MOS

2048 BITS/SEC AT
ENCOUNTER + 4 MOS

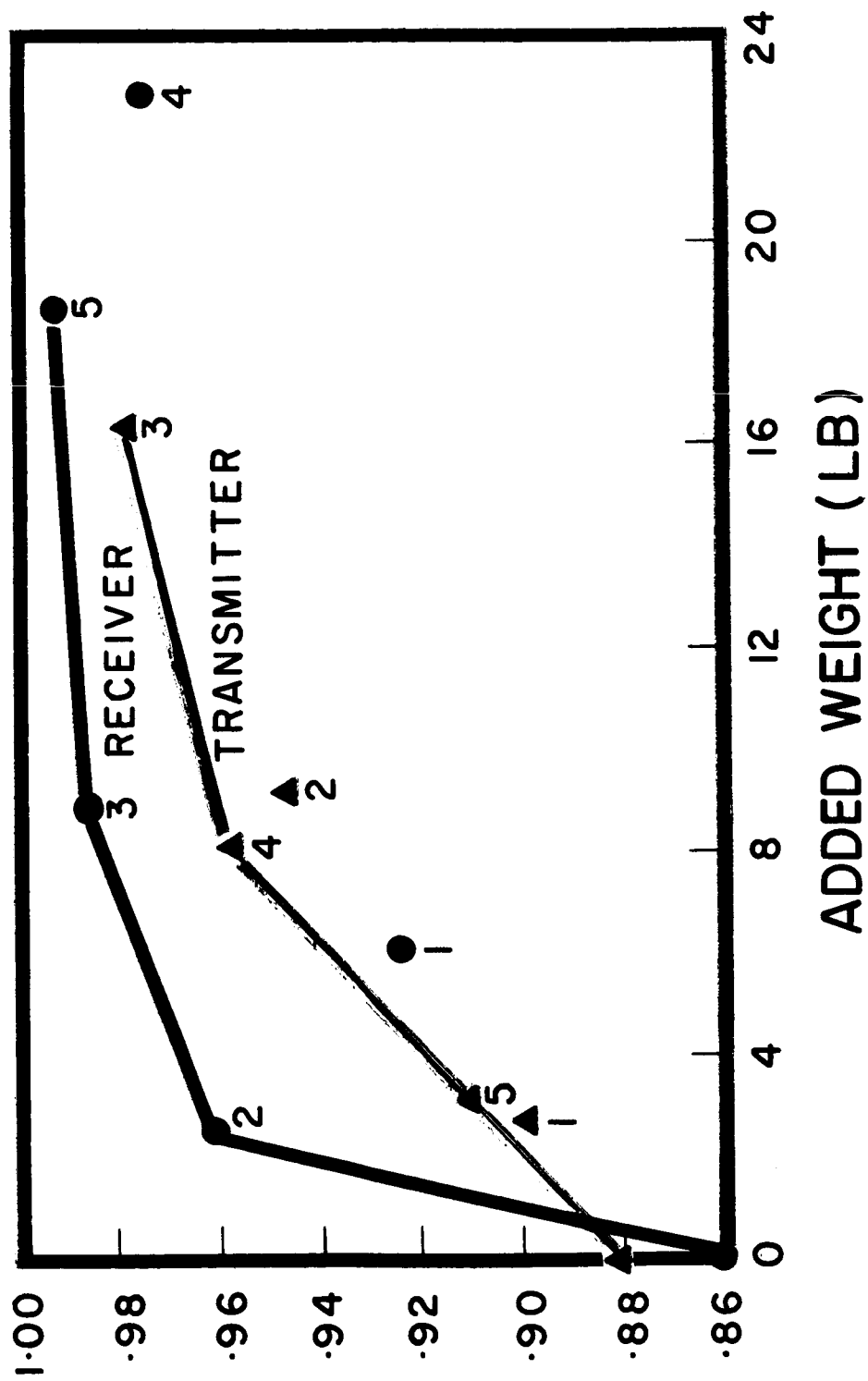
1024 BITS/SEC AT
MAX. EARTH-MARS RANGE

TAPE RECORDER SIZED
FOR 14.5 HRS AT 4096
BITS/SEC

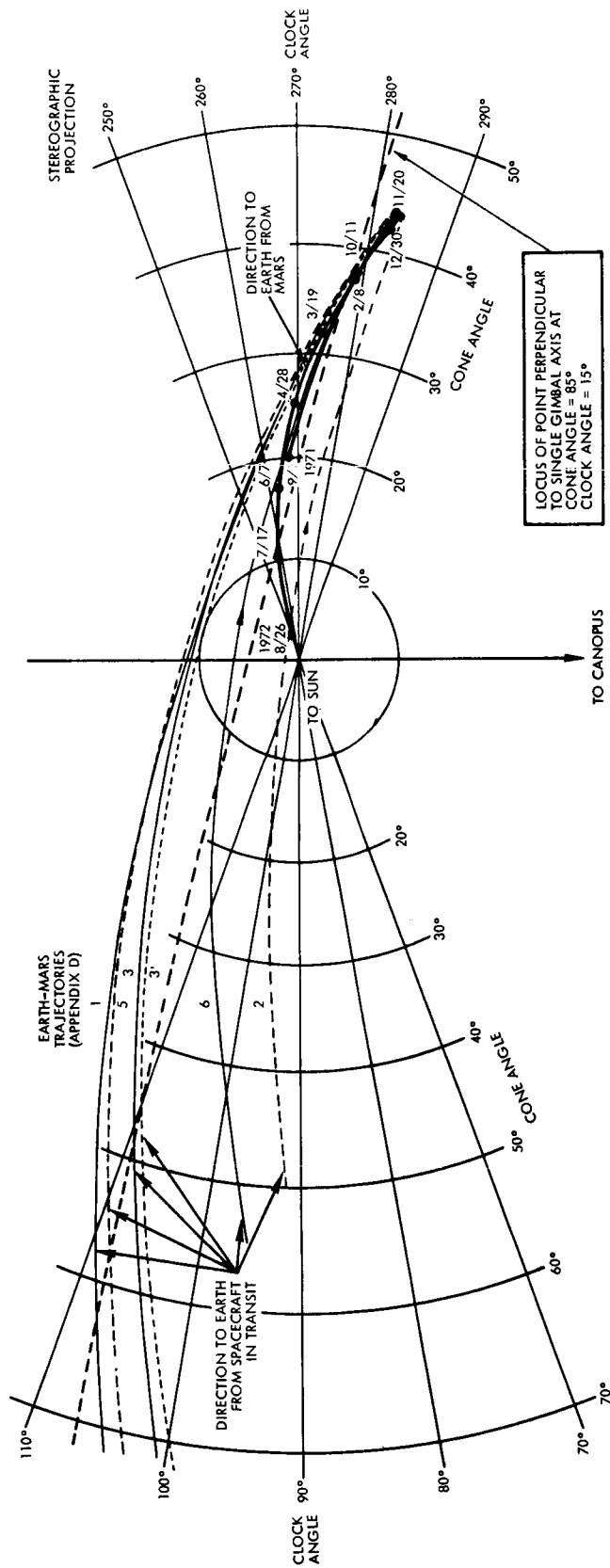
BASELINE S-BAND COMMUNICATION SYSTEM

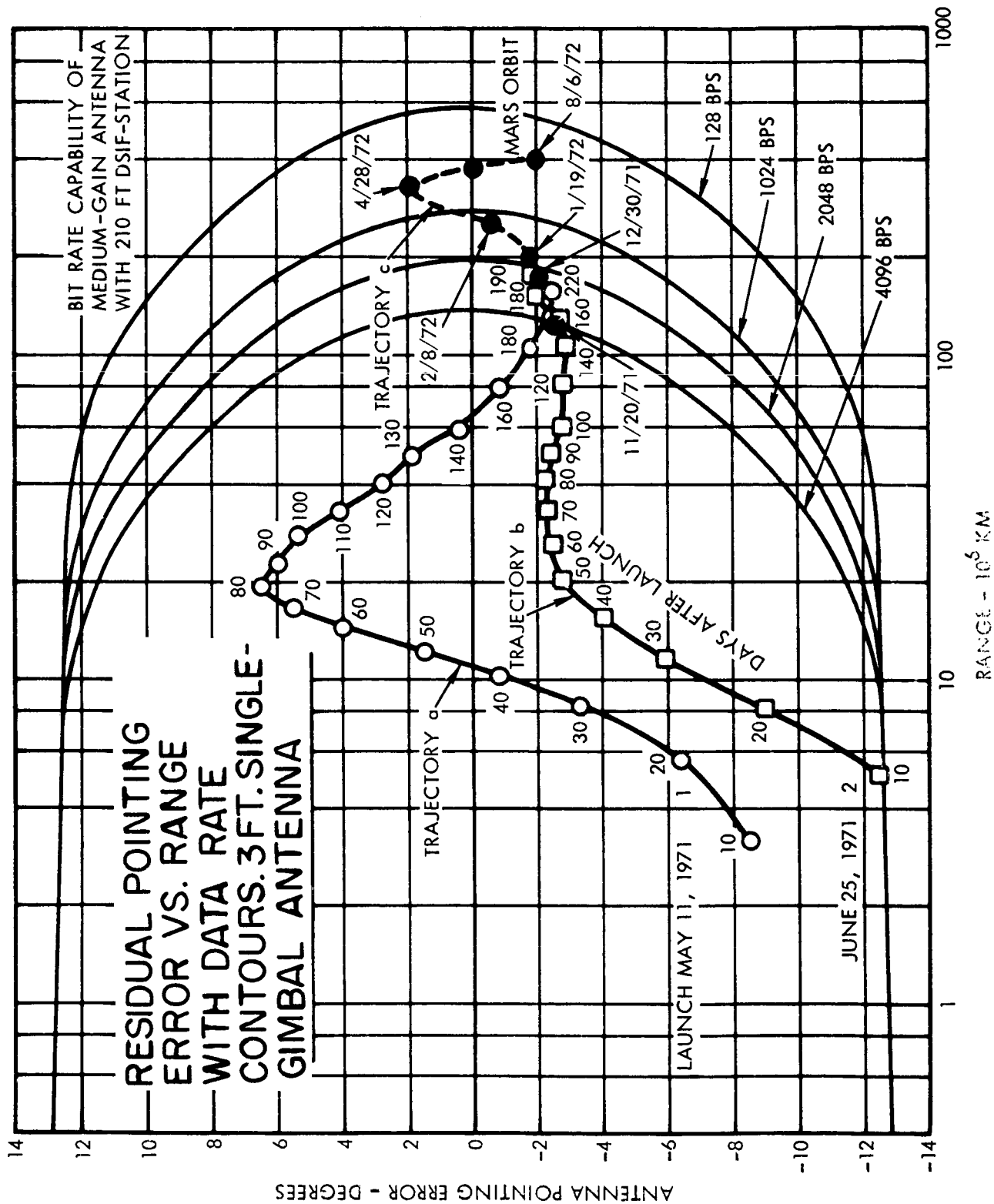


RELIABILITY ASSESSMENTS S-BAND RECEIVER AND TRANSMITTER

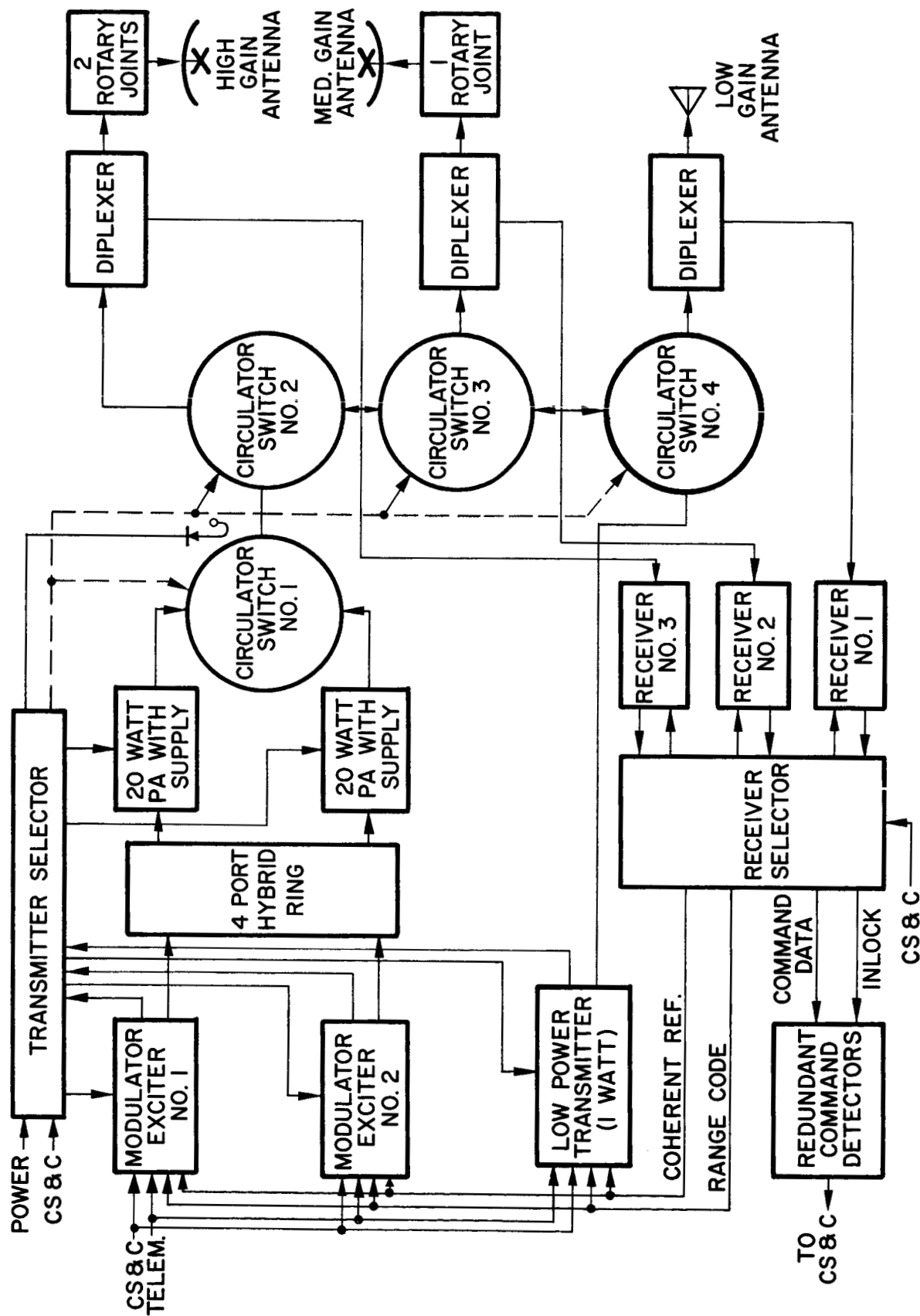


CONE AND CLOCK ANGLES OF EARTH AS SEEN FROM MARS, 1971





SELECTED S-BAND COMMUNICATION CONFIGURATION



REMAINING COMMUNICATION TRADEOFFS

IMPROVE LOW-GAIN ANTENNA PATTERN (ACHIEVE ROLL SYMMETRY) OR DEVELOP CANOPUS ACQUISITION WHICH PRECLUDES FALSE LOCK

SIMULTANEOUS COMMUNICATION WITH MULTIPLE SPACE-CRAFT AND CAPSULES

INCORPORATION OF HIGHER POWER TRANSMITTER OUTPUT TUBES AS THEY ARE DEVELOPED

DEVELOPMENT OF TUNNEL DIODE LOW NOISE PREAMPLIFIER

REDUCE FREQUENCY UNCERTAINTY IN CAPSULE RELAY LINK

USE OF SPACECRAFT AS REPEATER

ATLAS CENTAUR CAPABILITY

18001b SPACECRAFT TO MARS

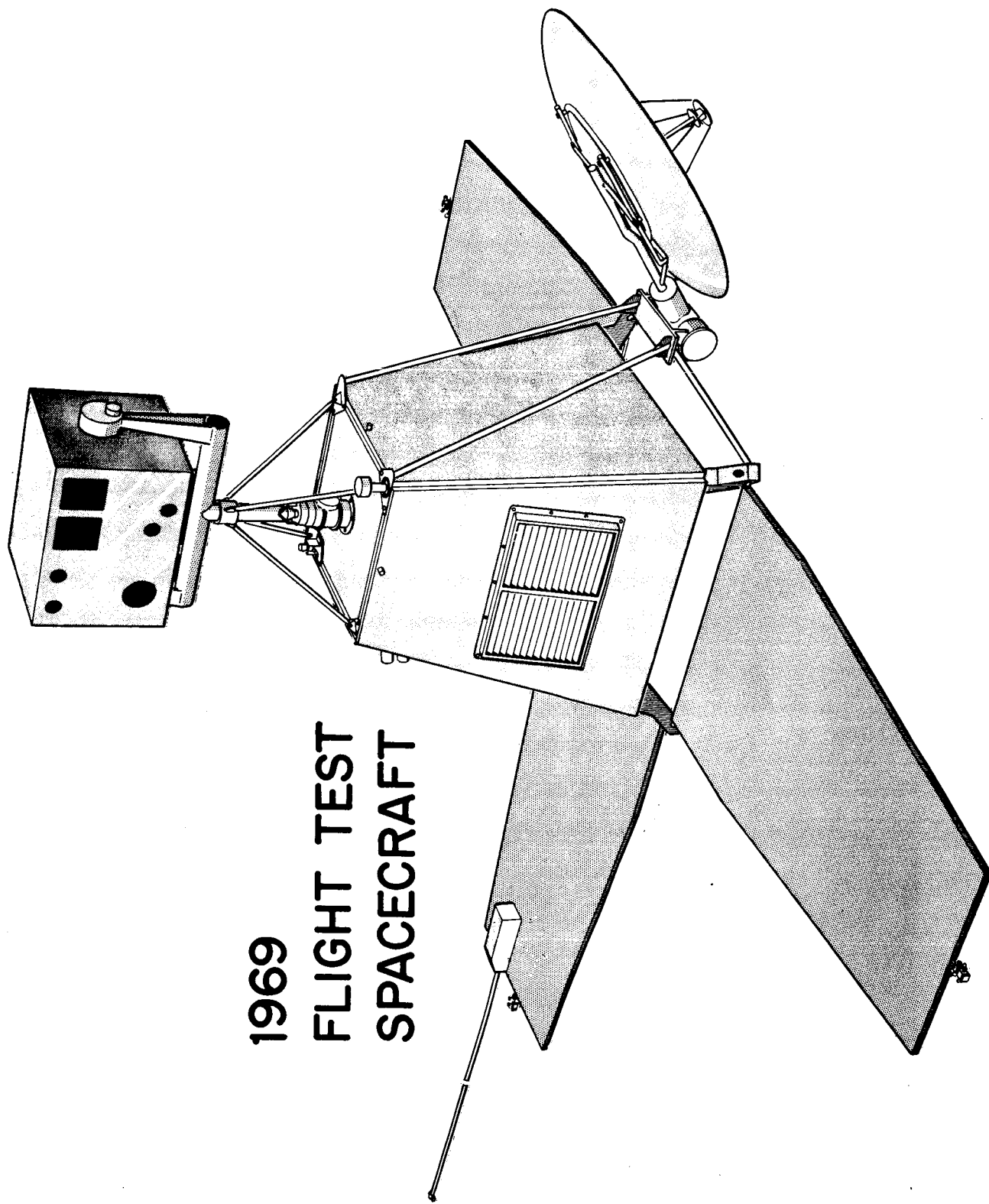
LAUNCH FEB 10, 1969 OR UP TO 100 DAYS LATER

ARRIVAL NOV 18, 1969 OR LATER

FLIGHT PATH

MARS FLYBY IS SUPERIOR TO EARTH ORBIT
OR INTERPLANETARY TRAJECTORIES

1969
FLIGHT TEST
SPACECRAFT



1969 FLIGHT TEST SPACECRAFT WEIGHTS

STRUCTURE	291 LB
OTHER MECHANICAL	45
TELECOMMUNICATIONS	136
POWER	224
COMMAND AND DISTRIBUTION	94
STABILIZATION AND CONTROL	72
MIDCOURSE PROPULSION	101
POP	104
SCIENCE PAYLOAD SIMULATORS	100
ENGINEERING INSTRUMENTATION	50
CONTINGENCY	89
	1306
ADAPTER	54
	1360
MARGIN	440
ATLAS-CENTAUR CAPABILITY	1800 LB

SPECIFIC OBJECTIVES

**EXERCISE AND OBSERVE ALL SUBSYSTEMS
IN ALL MODES**

MAKE MIDCOURSE CORRECTIONS

SIMULATE SCIENCE COMMANDS AND DATA

**SIMULATE CAPSULE SEPARATION AND
ORBIT INJECTION**

TRACK MARS WITH POP SENSORS

SIMULATE OR EXPERIENCE ECLIPSES

**MEASURE SPACE ENVIRONMENT
AFFECTING SPACECRAFT DESIGN**

VOYAGER SPACECRAFT SCHEDULE

