(24) ~~Fiche~~

42d

No

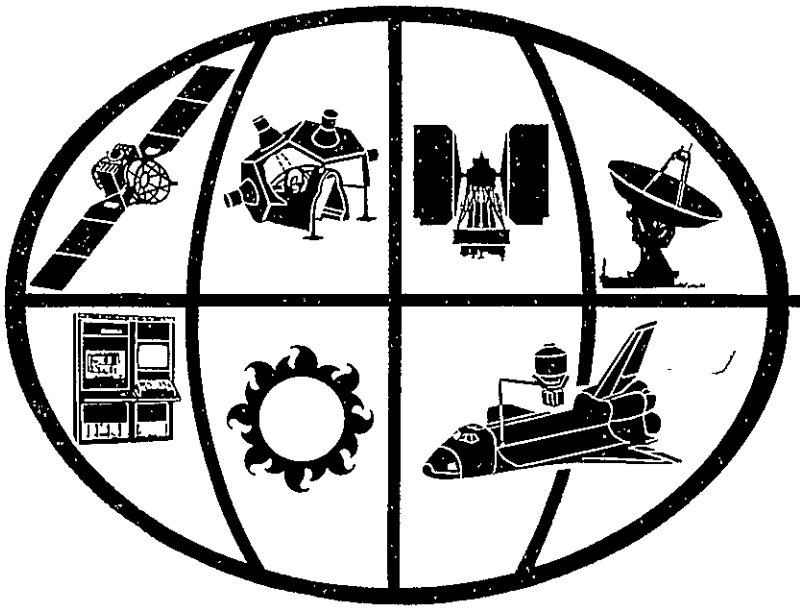
SOT-10

POST LANDSAT D
ADVANCED CONCEPT EVALUATION

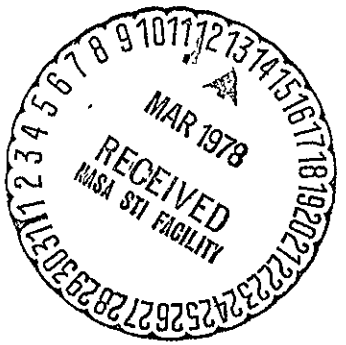
(NASA-CR-155769) POST LANDSAT D ADVANCED CONCEPT EVALUATION (PLACE) (General Electric Co.) 67 p HC A04/MF A01 CSCL 22A

N78-18499

Unclas
G3/43 06986



space division SD



MIDTERM BRIEFING
DECEMBER 1, 1977

GENERAL ELECTRIC

POST LANDSAT D
ADVANCED CONCEPT EVALUATION

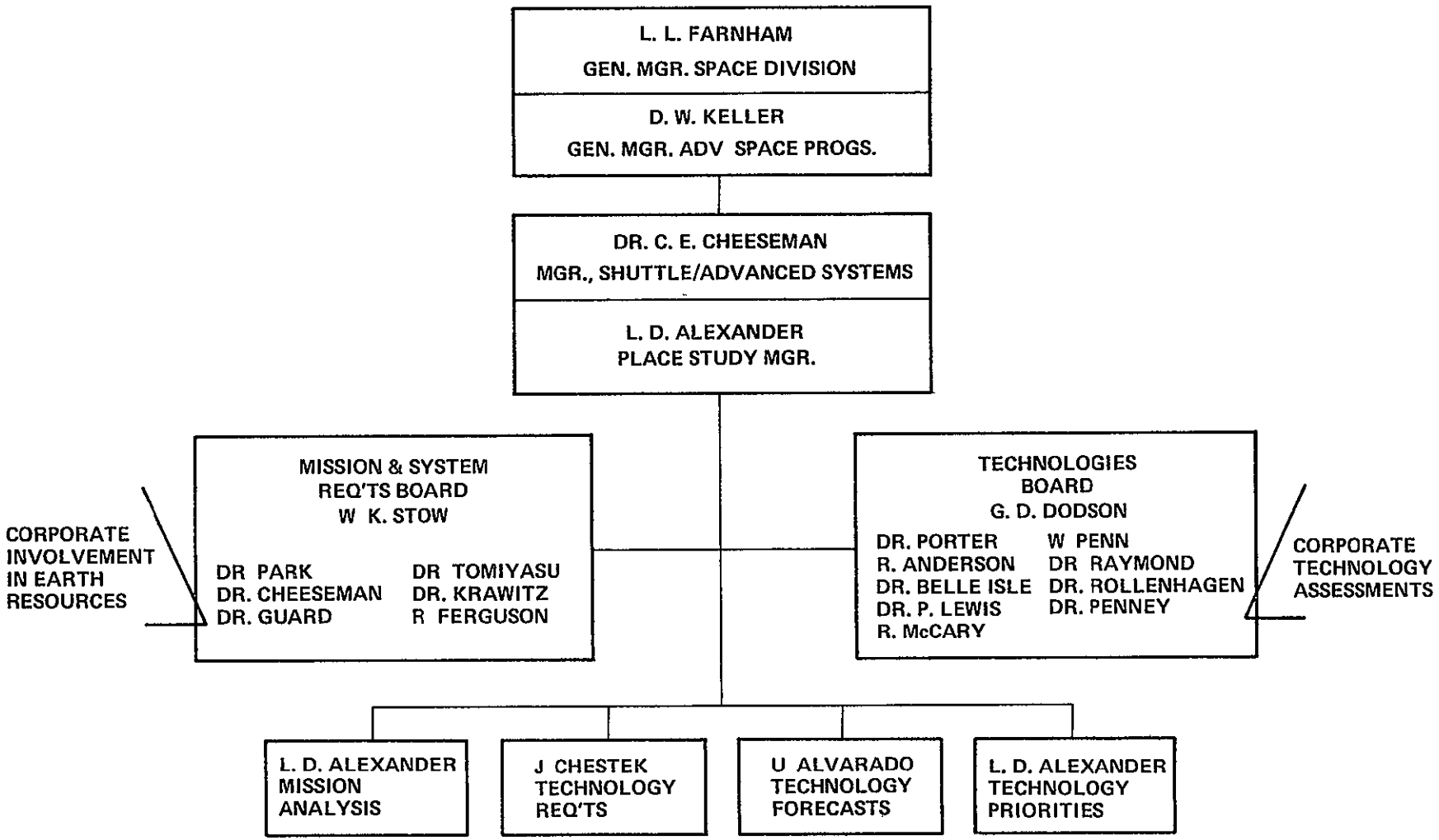
MIDTERM BRIEFING
DECEMBER 1, 1977

SPACE DIVISION

AGENDA

- INTRODUCTION
- MISSION OBJECTIVES AND REQUIREMENTS
- SYSTEM ELEMENTS
- SYSTEM CONCEPTS
- TECHNOLOGY REQUIREMENTS AND FORECASTING
- PRIORITY ANALYSIS

STUDY ORGANIZATION



SPACE DIVISION

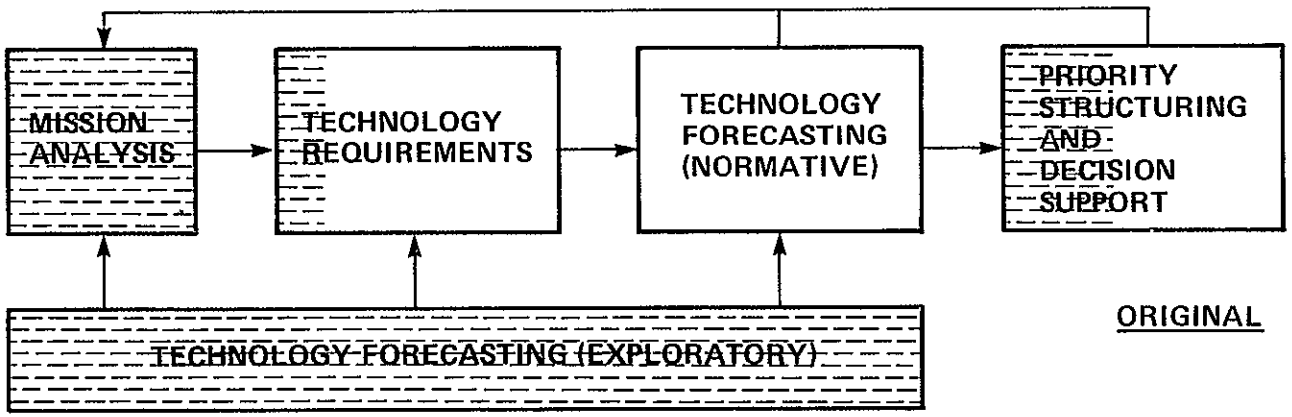
PLACE OBJECTIVES

- TO IDENTIFY THE KEY TECHNOLOGIES OF EARTH RESOURCES SATELLITE SYSTEMS OF THE POST '84 TIME PERIOD (1985-2000)
- TO PROVIDE A COMPREHENSIVE 'SPACE SYSTEMS TECHNOLOGY MODEL' FOR EARTH RESOURCES PROGRAMS FOR THIS PERIOD
- TO DEVELOP A TOOL TO ALLOW FOR PRIORITY STRUCTURING OF THESE KEY TECHNOLOGIES AS A DECISION AID

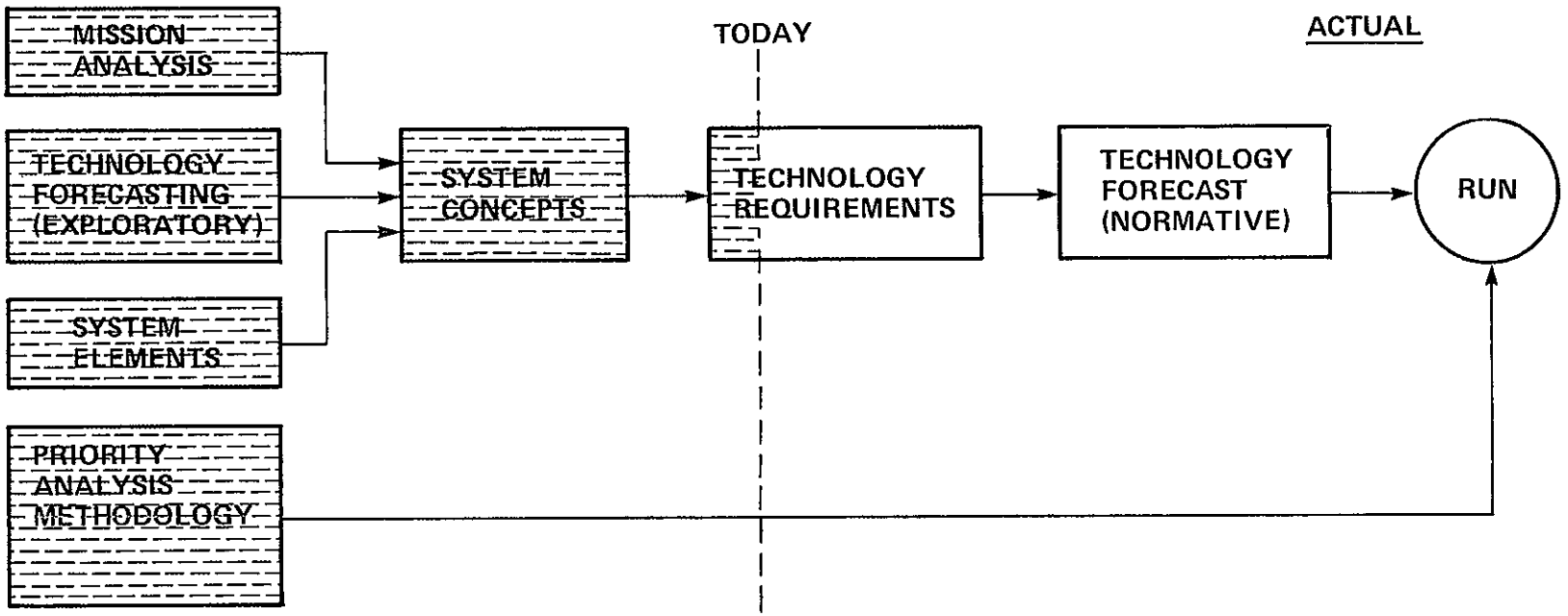
SPACE DIVISION

PLACE PROGRAM FLOW

PLACE NASA



ORIGINAL



ACTUAL

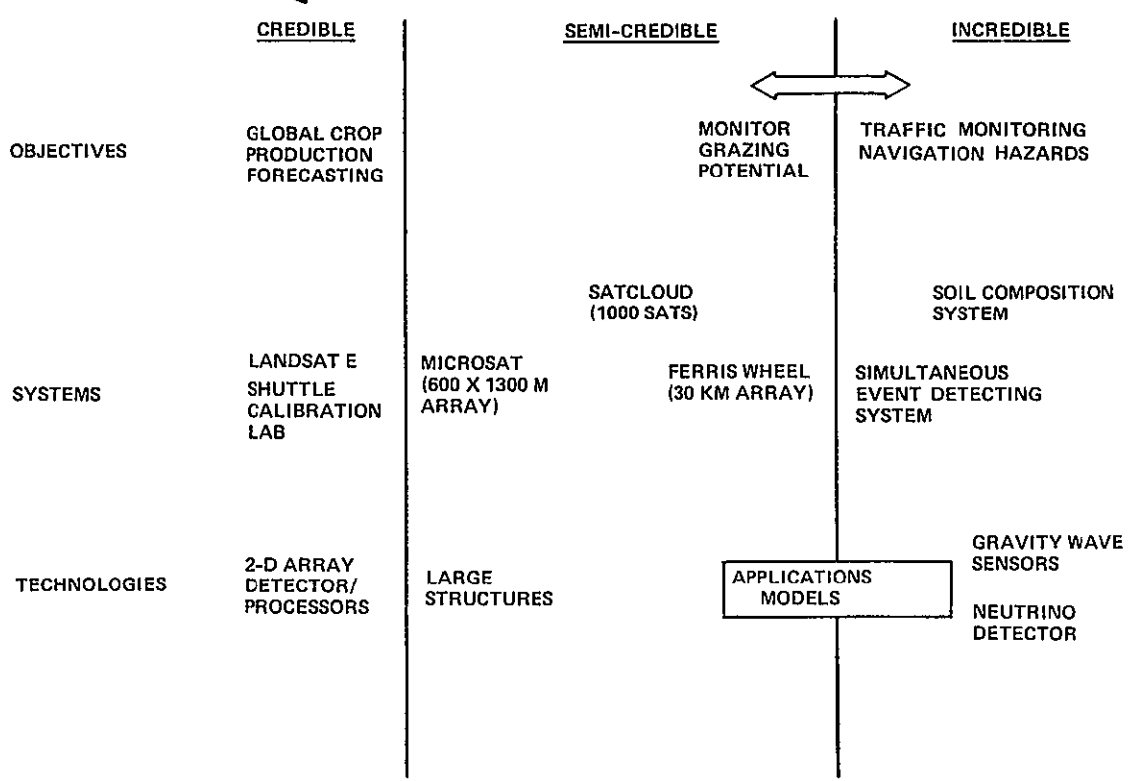
SPACE DIVISION

NASA MANDATE FOR VISION

PLACE

- STUDY SHOULD ATTEMPT TO EMPLOY IMAGINATION, VISION AND INSPIRATION. SEEK TO GO BEYOND THE CREDIBLE TO THE 'SEMI-CREDIBLE'
- IN BOTH MISSION ANALYSIS AND TECHNOLOGY FORECASTING — ASK WHAT 'CAN BE' RATHER THAN WHAT 'WILL BE.'

APPLIED AS



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STUDY DEFINITIONS

PLACE NASA

- MISSION CATEGORY — THE MAJOR AREAS TO BE STUDIED, E.G., AGRICULTURE, FORESTRY, ETC.
- MISSION OBJECTIVES — GOALS TO BE OBTAINED UNDER THE MAJOR CATEGORY HEADINGS, E.G., GLOBAL CROP PRODUCTION FORECASTING, WATER AVAILABILITY FORECASTING
- MISSION SUBOBJECTIVES — SUBGOALS REQUIRED TO FULFILL THE NEEDS OF MISSION OBJECTIVES E.G., SOIL MOISTURE MONITORING, CROP STRESS, ETC. SOME OF THESE MISSION SUBOBJECTIVES MAY BE USEFUL FOR MORE THAN ONE OBJECTIVE
- SYSTEM — A COMBINATION OF HARDWARE, SOFTWARE, AND PEOPLE REQUIRED TO PROVIDE DATA FOR THE VARIOUS MISSION OBJECTIVES, E.G., LANDSAT-D, GEOSYNCHRONOUS RADAR SATELLITE, ETC.
- PROGRAM — THE EFFORT AND RESOURCES THAT GO INTO THE DEVELOPMENT OF A SYSTEM
- SYSTEM SCENARIO — A SCHEDULE OF FUTURE SYSTEMS THAT ACCOMPLISH THE SET OF MISSION OBJECTIVES

SPACE DIVISION

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INTRODUCTION

MISSION OBJECTIVES AND REQUIREMENTS

SYSTEM ELEMENTS

SYSTEM CONCEPTS

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PRIORITY ANALYSIS

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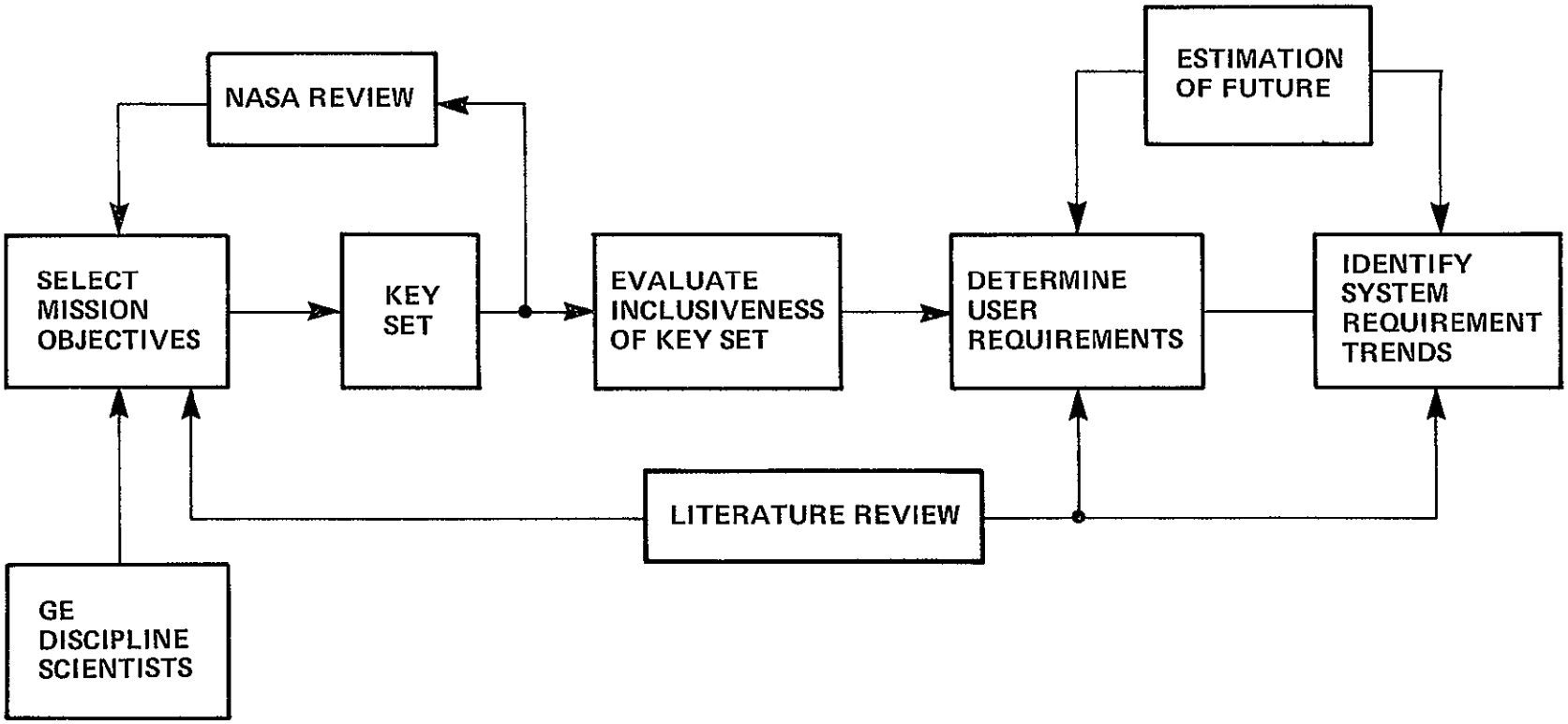
MISSION OBJECTIVES AND REQUIREMENTS

PLACE NASA



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PLACE GUIDELINES

PLACE NASA

- SPACECRAFT AND ASSOCIATED DATA PROCESSING FOR REMOTE SENSING OF THE EARTH
- EXCLUDED FROM CONSIDERATION:
  - WEATHER AND CLIMATE
  - EARTH AND OCEAN DYNAMICS
  - ENERGY/COMM/NAV
  - MILITARY APPLICATIONS
  - AIRCRAFT/DCP'S
  - EXTRATERRESTRIAL
  - CRIMINAL ACTIVITIES (EXCEPT POLLUTION)
- EIGHT KEY OBJECTIVES FOCUS PLACE STUDY

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KEY OBJECTIVES

PLACE

- AGRICULTURE — CROP PRODUCTION FORECASTING
  - IDENTIFY CROPS
  - MEASURE ACREAGE
  - ESTIMATE YIELD
  - MEASURE PRODUCTION
- RANGE MANAGEMENT — GRAZING POTENTIAL DETERMINATION
  - EVALUATE STATUS AND MEASURE CARRYING CAPACITY
  - ESTIMATE LIVESTOCK COUNT
  - ESTIMATE FORAGE PALATABILITY
- FORESTRY — TIMBER STAND VOLUME ESTIMATION
  - IDENTIFY TREES
  - EVALUATE QUANTITY AND QUALITY OF TIMBER
- GEOLOGY — GEOLOGICAL RESOURCES LOCATION
  - LOCATE ORES
  - LOCATE FOSSIL FUELS
  - LOCATE CONSTRUCTION MATERIALS
  - LOCATE GEOTHERMAL RESOURCES

SPACE DIVISION

KEY OBJECTIVES

PLACE NASA

- LAND USE — LAND USE AND CENSUS ENUMERATION
  - CREATE THEMATIC AND LAND USE MAPS
  - DETECT CHANGE IN LAND USE
  - ESTIMATE POPULATION
- WATER RESOURCES — WATERSHED MONITORING
  - MONITOR SURFACE SUPPLY OF FRESH WATER
  - MEASURE GROUNDWATER FLOW AND STORAGE
  - INTEGRATE RAINFALL AND EVAPORATION DATA
- ENVIRONMENTAL QUALITY — WATER POLLUTION DETECTION
  - DETECT, MONITOR, AND TRACE FRESH WATER POLLUTANTS
  - MONITOR EUTROPHICATION
  - MEASURE SALT WATER INCURSION
- DISASTER ASSESSMENT — ABRUPT EVENT EVALUATION
  - MONITOR AND ASSESS DISASTERS
  - MONITOR NON-CALAMITOUS ABRUPT EVENTS

SPACE DIVISION

USER REQUIREMENTS TO SATISFY OBJECTIVES OF KEY SET IN 2000

PLACE

	PRECISION	PARAMETER RANGE	OBSERVATION FREQUENCY	RESPONSE TIME	
CROP PRODUCTION FORECASTING					
IDENTIFY CROPS		98%	ALL	8 DA	2 WK
MEASURE ACREAGE		98%	>1 HA	8 DA	2 WK
ESTIMATE YIELD		95%	ALL	3 DA	1 WK
DETERMINE PRODUCTION		90%		8 DA	3 WK
GRAZING POTENTIAL DETERMINATION					
IDENTIFY VEGETATION		90%	ALL	1 MO	3 MO
ESTIMATE PALATABILITY				1 WK	3 DA
MEASURE FORAGE BIOMASS		90%		4 DA	4 DA
EVALUATE RANGE PHYSICAL CONDITION				1 DA	6 HR
TIMBER STAND VOLUME ESTIMATION					
IDENTIFY TREES		90%	ALL	1 YR	1 YR
DETERMINE DENSITY DISTRIBUTION		95%		1 YR	1 YR
MEASURE HEIGHT AND DIAMETER		90%	ALL	1 YR	1 YR
DETECT INSECT AND DISEASE ATTACK		80%		1 MO	2 WK
GEOLOGICAL RESOURCES LOCATION					
LOCATE ORES		90%	10^7KG	ONCE	1 YR
LOCATE CONSTRUCTION MATERIALS		70%	10^3M^3	ONCE	1 YR
LOCATE FOSSIL FUELS		95%	10^4M^3	ONCE	1 YR
LOCATE GEOTHERMAL RESOURCES		75%		1 YR	1 YR

SPACE DIVISION

USER REQUIREMENTS TO SATISFY OBJECTIVES OF KEY SET IN 2000 (CONTINUED)

PLACE NASA

	PRECISION	PARAMETER RANGE	OBSERVATION FREQUENCY	RESPONSE TIME	
LAND USE AND CENSUS ENUMERATION					
MAP LAND USE TO LEVEL III	98%			1 YR	6 MO
DETECT CHANGE IN LAND USE	95%			2 MO	4 MO
PERFORM DEMOGRAPHIC CENSUS	95%			2 YR	1 YR
WATERSHED MONITORING					
MEASURE SNOW AND ICE VOLUME	80%		$>100M^3$	3 DA	1 DA
MEASURE STREAM AND RIVER FLOW	90%		ALL	3 HR	1 HR
MEASURE LAKE AND RESERVOIR VOLUME	95%		$>100M^3$	1 DA	1 DA
WATER POLLUTION DETECTION					
DETECT, IDENTIFY, AND MONITOR POLLUTANTS	85%			2 HR	30 MN
MONITOR EUTROPHICATION				2 WK	1 MO
MEASURE SALT WATER INCURSION				3 DA	1 DA
ABRUPT EVENT EVALUATION					
MONITOR AND ASSESS DISASTERS	95%			DEMAND	1 MN
MONITOR NON-CALAMITOUS ABRUPT EVENTS	90%			DEMAND	1 HR

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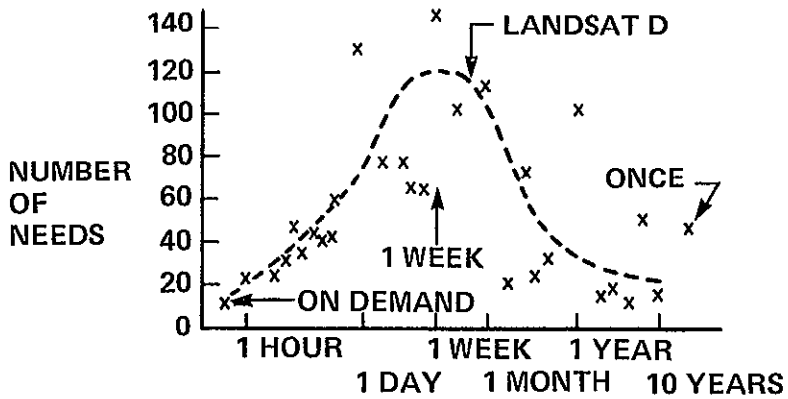
USER AND SYSTEM REQUIREMENTS: SOME DISTRIBUTIONS

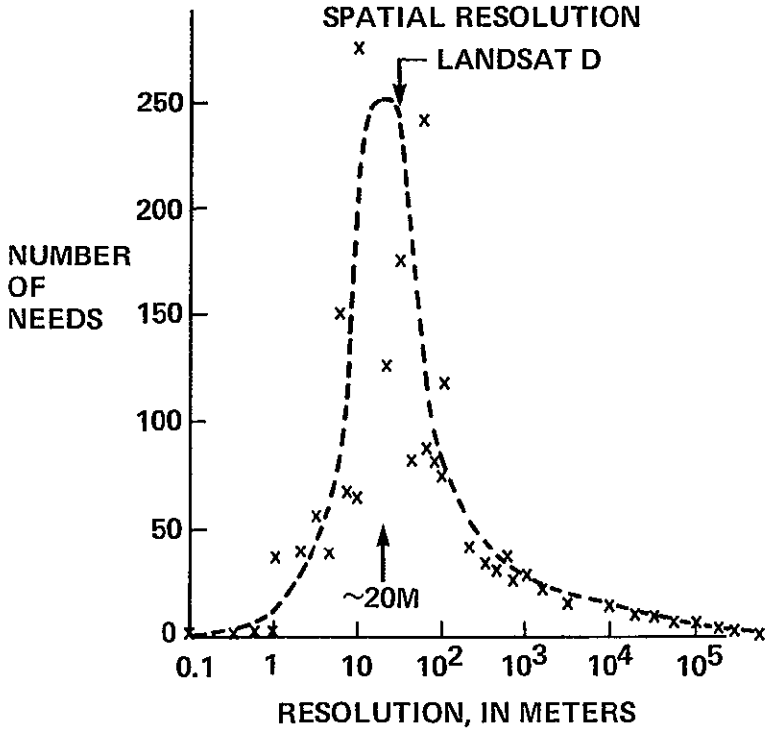
PLACE NASA

FREQUENCY OF OBSERVATION



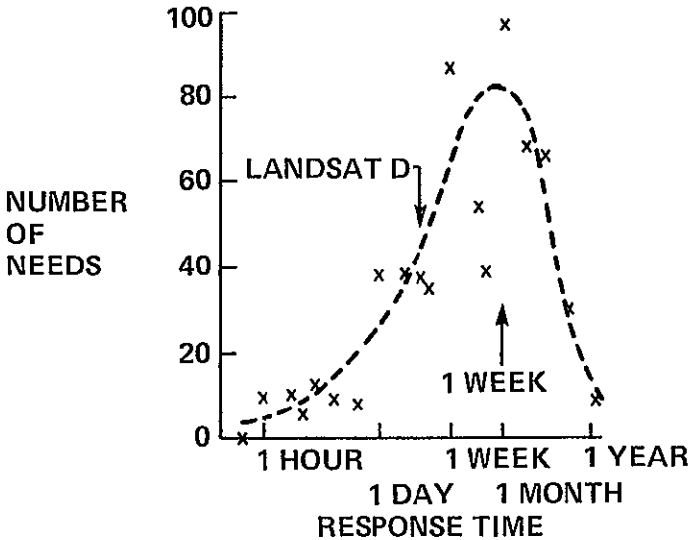
FREQUENCY OF OBSERVATION

SPATIAL RESOLUTION



RESOLUTION, IN METERS

RESPONSE TIME



RESPONSE TIME

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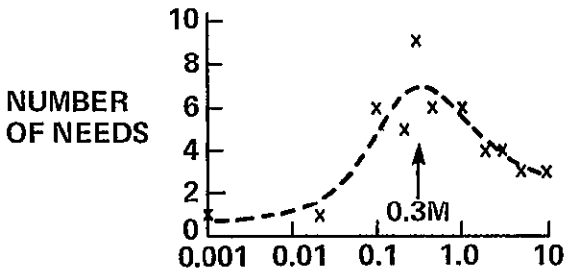
VERTICAL RESOLUTION



VERTICAL (DEPTH) RESOLUTION IN METERS

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TRENDS IN REQUIREMENTS AND CAPABILITIES

PLACE NASA

- IFOV DOWN TO 5-10 METER
- AMPLITUDE RESOLUTION TO 0.1-0.5% (8-10 BITS)
- DATA RATE TO GIGABIT/SEC RANGE
- VARIABLE RESOLUTION/ZOOM CAPABILITY
- MAKE OBSERVATIONS IN ANY WEATHER, DAY OR NIGHT, UP TO REAL TIME
- MORE USE OF MODELS AND DATA BANKS

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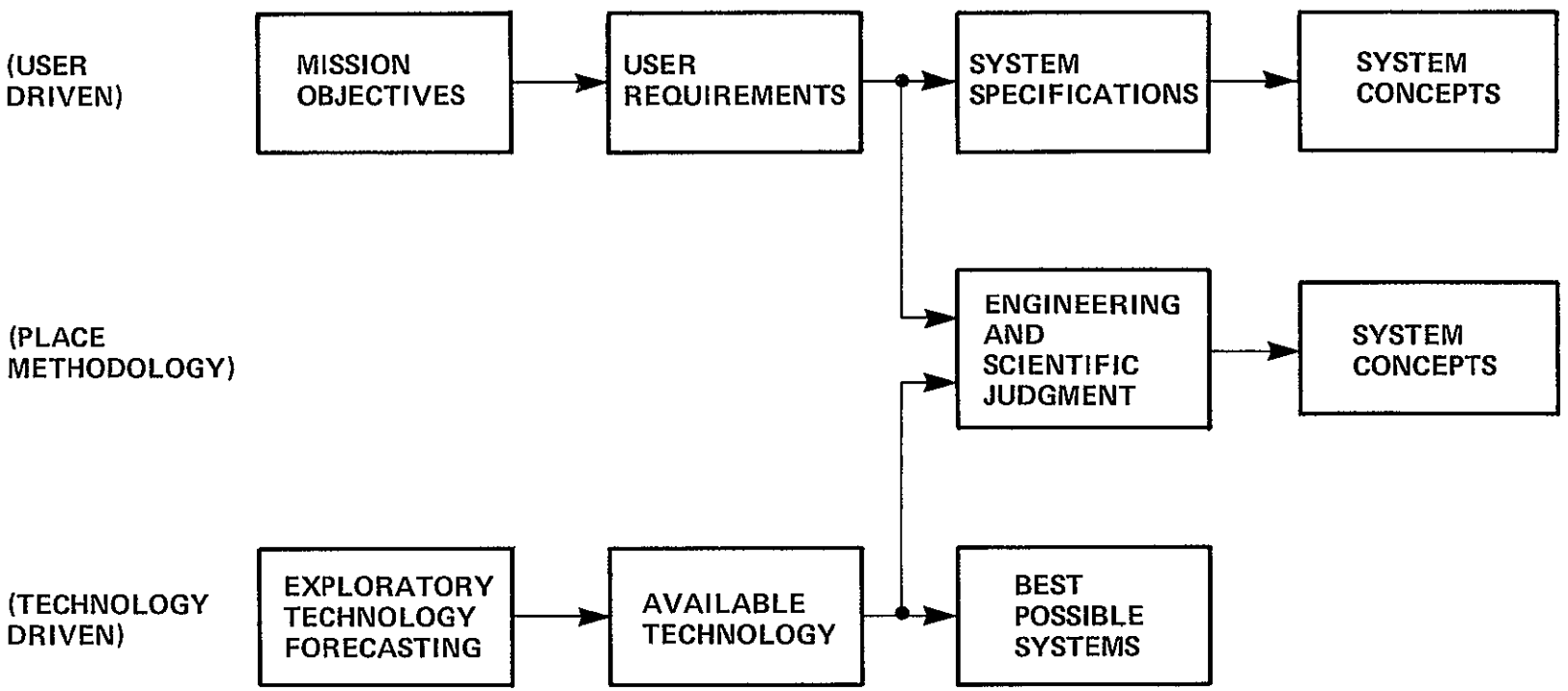
FORMATION OF SYSTEM CONCEPTS



SPACE DIVISION

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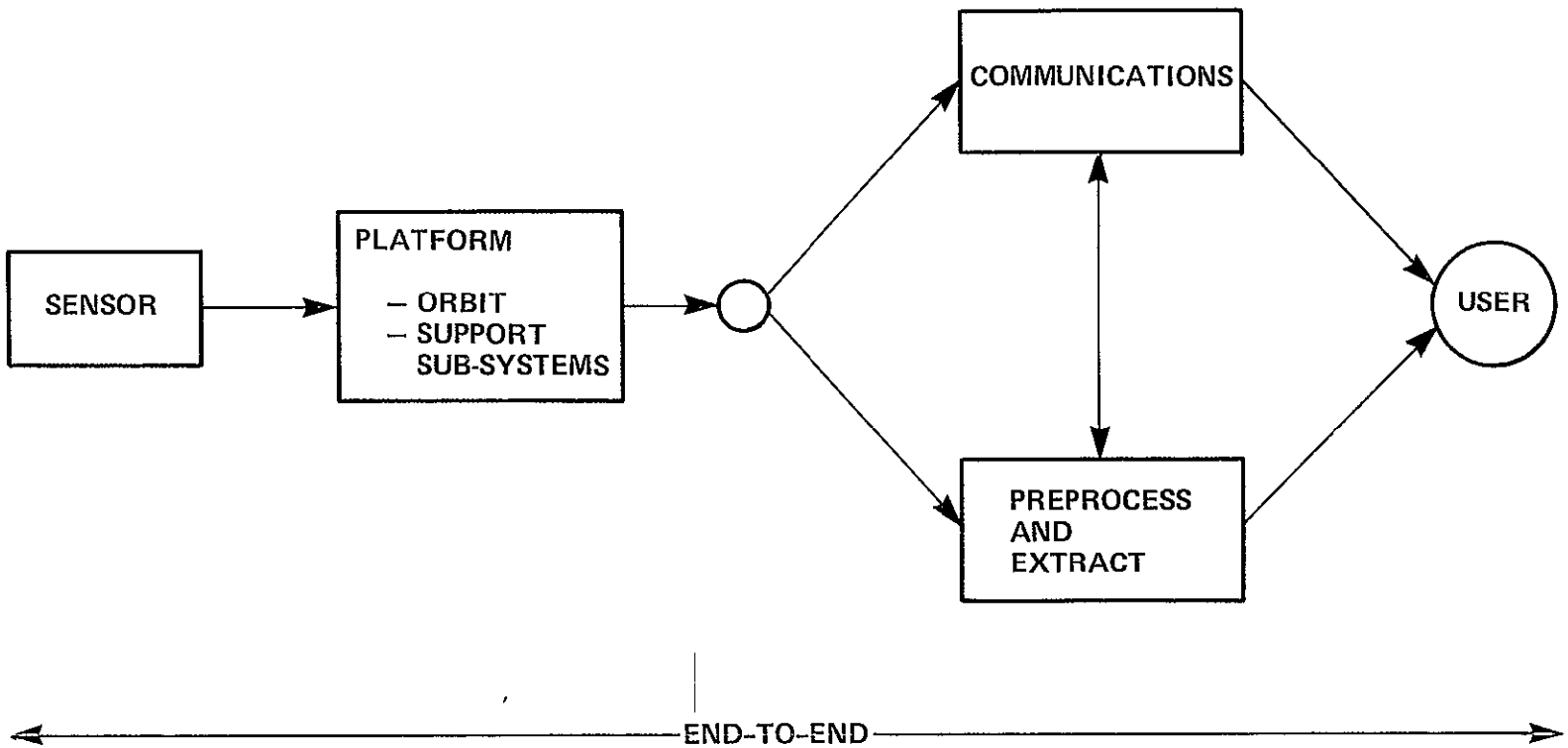
SPACE DIVISION

SYSTEM ELEMENTS



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SENSORS

PLACE NASA

- VISIBLE/IR IMAGERS
  - PASSIVE – PUSH BROOM, WHISK BROOM, SOLID STATE CAMERAS
  - ACTIVE – ATMOSPHERIC CALIBRATION, FLUORESCENCE, NIGHT IMAGING
  - SMART SENSORS
- MICROWAVE IMAGERS/ALTIMETERS
  - SYNTHETIC APERTURE RADAR – LEO, GEOSYNCHRONOUS
  - REAL APERTURE RADAR – GEOSYNCHRONOUS,HOLOGRAPHY, LEO
  - RADIOMETER
  - ALTIMETER
- TEXTURE MEASURING SENSORS
  - OPTICAL
  - SWEEP FREQUENCY RADAR – SCATTEROMETER
- FIELD MEASURING SENSORS
  - MAGNETIC
  - GRAVITY

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PLACE FAMILY ORBITS

PLACE NASA

- SPACE SHUTTLE SORTIE
- LANDSAT CLASS — SUN SYNCHRONOUS
- EARTH WATCH
- 24 HOUR ORBITS

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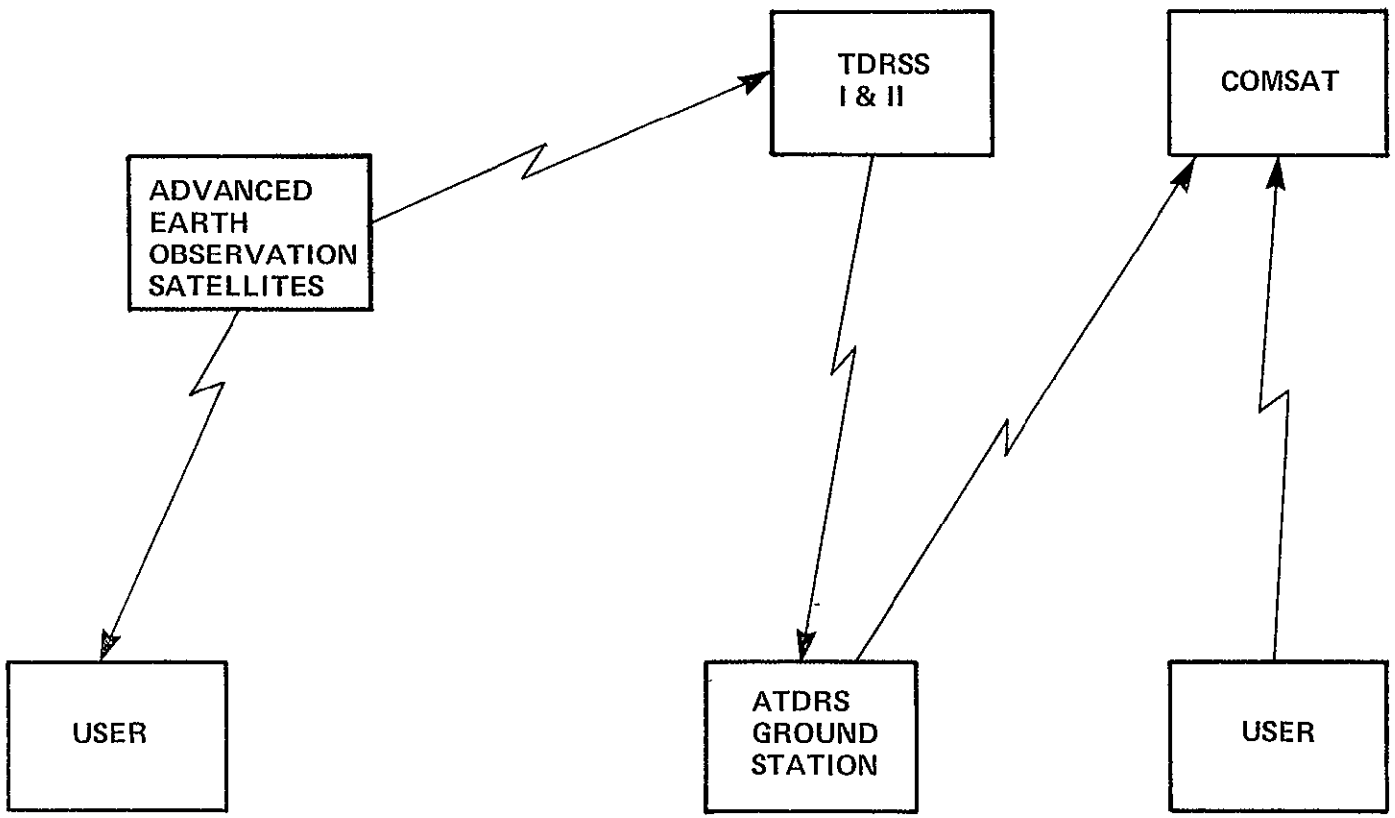
COMMUNICATIONS NEEDS (1985-2000)

PLACE NASA



EACH LINK MAY CONTAIN RAW DATA, PROCESSED DATA, OR RESOURCE MANAGEMENT INFORMATION

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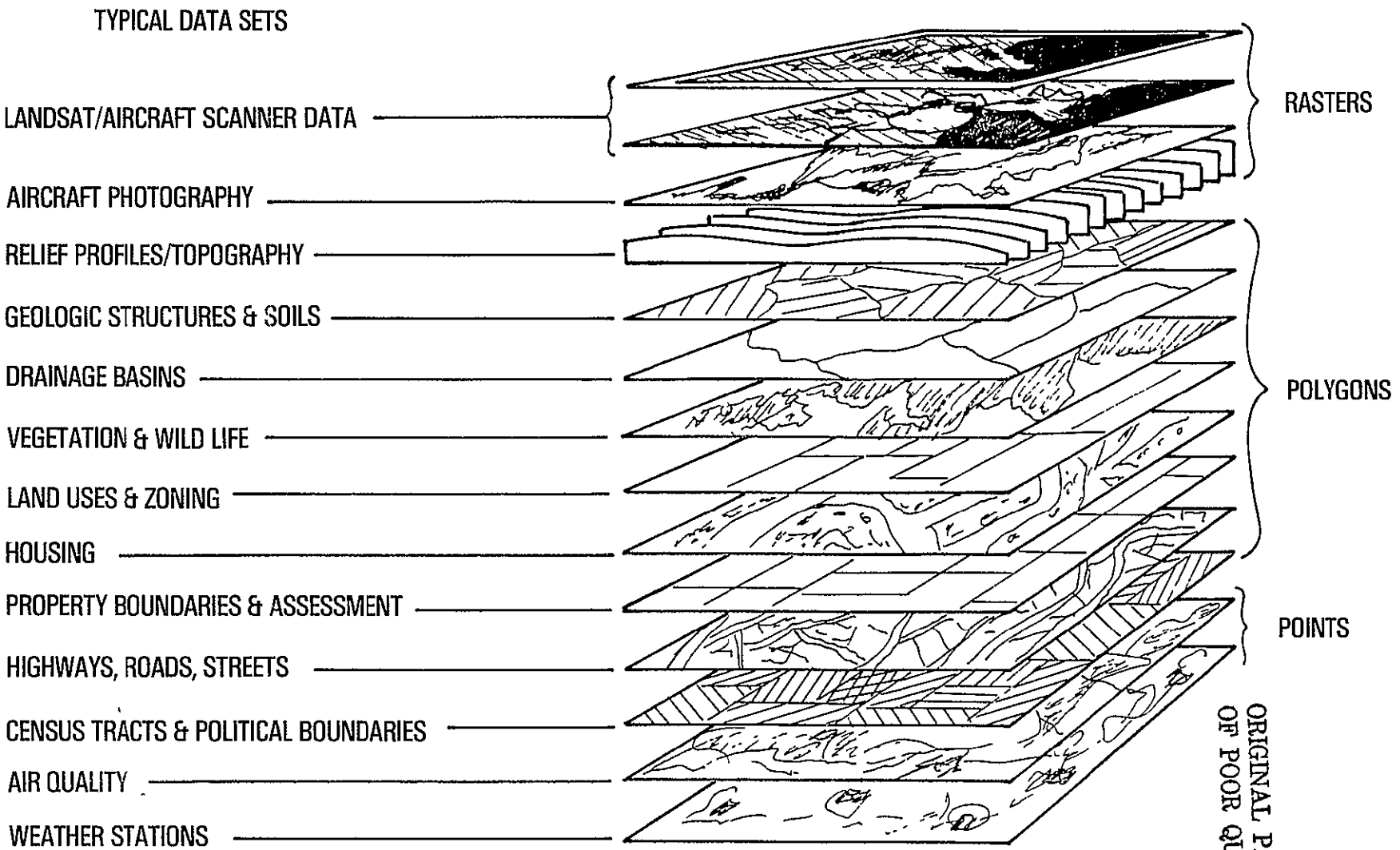
GEO-REFERENCED LAND INFORMATION DATA BASE SYSTEM CONCEPT

PLACE NASA



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AGENDA

PLACE NASA

INTRODUCTION

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SYSTEM ELEMENTS

➡ SYSTEM CONCEPTS

TECHNOLOGY REQUIREMENTS AND FORECASTING

PRIORITY ANALYSIS

SPACE DIVISION

EXPLORATORY TECHNOLOGY FORECASTING

PLACE NASA

- OBJECTIVE
  - IDENTIFY MISSION ENABLING CONCEPTS
- METHODS
  - "BLUE SKY" MEETINGS
  - LITERATURE SEARCH
  - PERSONAL CONTACTS
  - "IMAGINEERING"
- RESULTS
  - SENSING CONCEPTS
  - PLATFORM/SUPPORT CONCEPTS
  - DATA SYSTEM CONCEPTS

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SENSOR AND SYSTEM CONCEPTS

PLACE NASA

*1. LANDSAT H

*2. EARTHWATCH

3. SEOS

*4. TEXTUROMETER

5. HCMM FOLLOW-ON

6. NITE-LITE

*7. MICROSAT

8. PARASOL RADIOMETER

*9. RADAR ELLIPSOMETER

*10. FERRIS WHEEL RADAR

*11. SATCLOUD

12. RADAR ALTIMETER

13. SWEEP FREQUENCY RADAR

*14. GEOSYNCHRONOUS SAR

15. RADAR HOLOGRAPHER

16. FARADAY MAGSAT

17. TETHERSAT

18. SHUTTLE CALIBRATION FACILITY

19. OPERATIONAL SHUTTLE FLIGHTS

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SYSTEM CONCEPTS

PLACE

1. LANDSAT E (OPS. + HRPI)
2. LANDSAT F (OPTICAL IMAGER (DEVELOPMENTAL)
3. LANDSAT G (S.A.R. DEVELOPMENTAL)
* 4. LANDSAT H
5. EARTHWATCH (DEVELOPMENTAL)
* 6. EARTHWATCH
7. SEOS-I (DEVELOPMENTAL)
8. SEOS-II (3 M. RESOLUTION-OPERATIONAL)
9. TEXTUROMETER (DEVELOPMENTAL)
* 10. TEXTUROMETER
11. HCMM FOLLOW-ON
12. NITE-LITE (DEVELOPMENTAL)
13. NITE-LITE
14. SHUTTLE MICROWAVE EXPERIMENTS
15. MICROWAVE TEST SATELLITE
* 16. MICROSAT
17. PARASOL RADIOMETER
18. RADAR ELLIPSOMETER (DEVELOPMENTAL)
* 19. RADAR ELLIPSOMETER
20. FERRIS WHEEL (EXPERIMENTAL)
* 21. FERRIS WHEEL RADAR
22. SATCLOUD (EXPERIMENTAL)
23. SATCLOUD (DEVELOPMENTAL)
* 24. SATCLOUD
25. SHUTTLE ALTIMETER (EXPERIMENTAL)
26. RADAR ALTIMETER (DEVELOPMENTAL)
27. RADAR ALTIMETER
28. SWEEP FREQUENCY RADAR (DEVELOPMENTAL)
29. SWEEP FREQUENCY RADAR
30. GEOSYNCHRONOUS SAR (DEVELOPMENTAL)
* 31. GEOSYNCHRONOUS SAR
32. RADAR HOLOGRAPHER (DEVELOPMENTAL)
33. RADAR HOLOGRAPHER
34. FARADAY MAGSAT
35. TETHERSAT
36. SHUTTLE CALIBRATION FACILITY
37. OPERATIONAL SHUTTLE FLIGHTS

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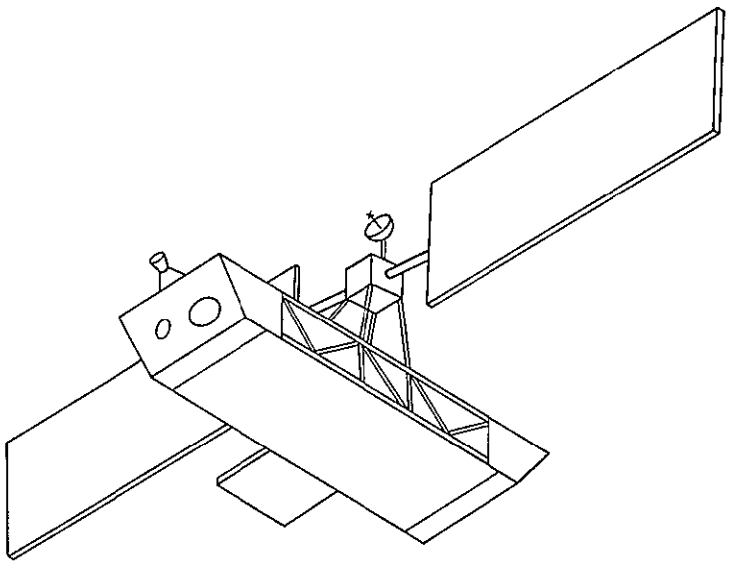
LANDSAT H — SYSTEM CONCEPT

PLACE NASA



- EXTENSION OF OPERATIONAL LANDSAT PROGRAM (APPROX. 1995)
- INCORPORATES OPTICAL AND SAR DEVELOPMENTS OF LANDSAT F AND G
- SMART OPTICAL SENSOR ALLOWS FOR INTELLIGENT ON-BOARD EDITING/DATA REDUCTION
- SYNTHETIC APERTURE RADAR PROVIDES MULTI-FREQUENCY, ALL WEATHER IMAGING CAPABILITY
- ON-BOARD PROCESSING AND STORAGE ALLOWS FOR CHANGE DETECTION AND OR INFORMATION EXTRACTION
- HIGH RESOLUTION POINTABLE IMAGER PROVIDES GREATER DETAIL IN SELECTED TARGET AREAS
- ACTIVE VISIBLE SENSOR PROVIDES ATMOSPHERIC CALIBRATION, LUMINESCENCE, NIGHT IMAGING

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LANDSAT H — SYSTEM CONCEPT (CONTINUED)

PLACE NASA

PERFORMANCE PARAMETERS

- SMART VISIBLE/IR SENSOR
  - — FORWARD/BACKWARD LOOKING
  - — 10 M RESOLUTION
  - — 3 FORWARD BANDS/7 BACKWARD
  - — 1.25 GBPS DATA RATE
  - — 185 KM SWATH WIDTH
- SYNTHETIC APERTURE RADAR
  - — L, C, X-BAND
  - — 25 METER RESOLUTION
- HIGH RESOLUTION POINTABLE IMAGER
  - — 5 M RESOLUTION
  - — 5 KM x 5 KM TARGETS
  - — 4 SPECTRAL BANDS
- LASER ATMOSPHERIC CALIBRATION
  - — ALSO USED FOR LUMINESCENCE, NIGHT IMAGING
- ORBIT-SUN SYNCHRONOUS — (700 - 900 KM)
  - — 3 SPACECRAFT CONSTELLATION
  - — 6 DAY REPEAT CYCLE

SYSTEM CONSIDERATIONS

MISSIONS CONTRIBUTED TO: ALL

RELATED SPACECRAFT: EARTHWATCH
SAT CLOUD
GEOSYNCHRONOUS SAR
RADAR HOLOGRAPHER

TIME PROJECTION: 1992 - 1997

MEASURE OF RISK: MEDIUM

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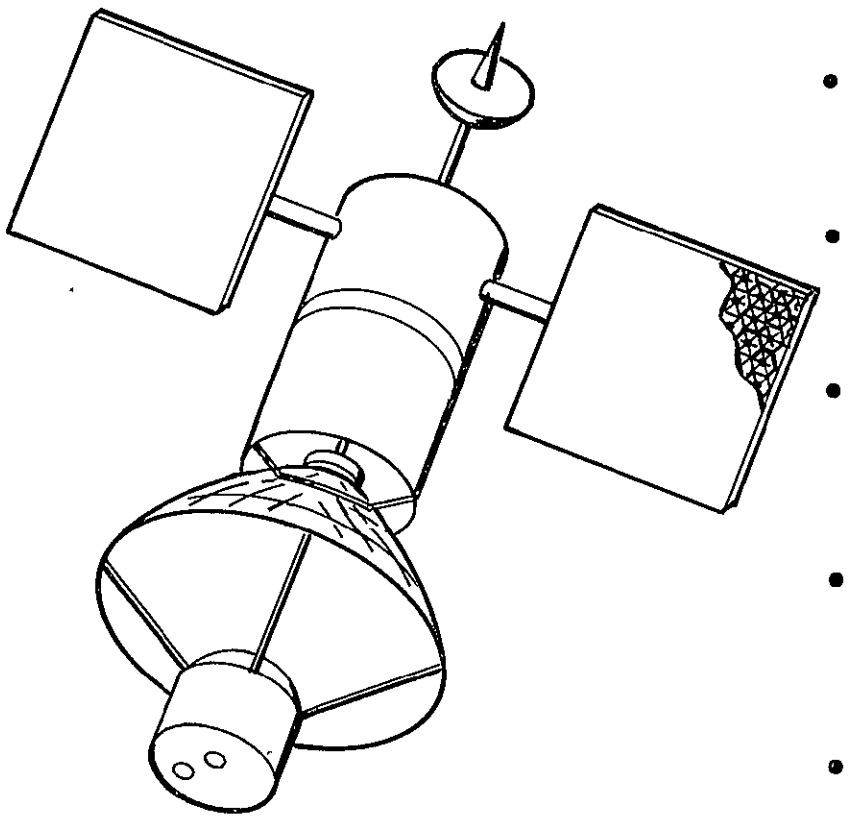
EARTHWATCH — SYSTEM CONCEPT

PLACE NASA



- INTERMEDIATE (SUBSYNCHRONOUS) ORBITS ORIGINALLY SUGGESTED BY ASTRONAUT BILL POGUE
- 3000-6000 MILE REPEATING ORBITS — PROVIDE NEAR CONTINUOUS EARTH COVERAGE
- COULD PROVIDE BOTH EARTH RESOURCES MANAGEMENT INFORMATION (MAPPING) AND QUICK-LOOK CAPABILITY (DISASTER ASSESSMENT)
- 2 POINTABLE OPTICAL SENSORS
  - HI-RES FOR QUICK-LOOK CAPABILITY
  - MED-RES FOR MAPPING CAPABILITY
- SYNTHETIC APERTURE RADAR/RADIOMETER FREQUENCY SHARE THE SAME ANTENNA

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EARTHWATCH — SYSTEM CONCEPT (CONTINUED)

PLACE

PERFORMANCE PARAMETERS

- ORBIT PERIOD OF 6 HOURS (INERTIAL FRAME)
- 20 SATELLITES IN CONSTELLATION
- CONTINUOUS COVERAGE OF THE ENTIRE GLOBE WITH ELEVATION ANGLE >20°
- POINTABLE SENSORS REQUIRED
- VISIBLE/IR IMAGER
  - 3-6 M RESOLUTION
    TARGETS OF $(5\ KM)^2$ - 2.7 M PIXELS
  - 30 M RESOLUTION
    90 K x 90 K IMAGES - 9 M PIXELS
- PASSIVE RADIOMETER — 15 M ANTENNA
  - X-BAND — 12 KM RESOLUTION
  - S-BAND — 60 KM RESOLUTION
  - L-BAND — 120 KM RESOLUTION
- SYNTHETIC APERTURE RADAR
  - 10-25 M RESOLUTION
  - X-BAND, S-BAND, L-BAND

SYSTEM CONSIDERATIONS

MISSIONS CONTRIBUTED TO: ALL

RELATED SPACECRAFT: LANDSAT
SEOS
SATCLOUD
GEOSYNCHRONOUS SAR
RADAR HOLOGRAPHER

TIME PROJECTION: 1992-1997

MEASURE OF RISK: MEDIUM

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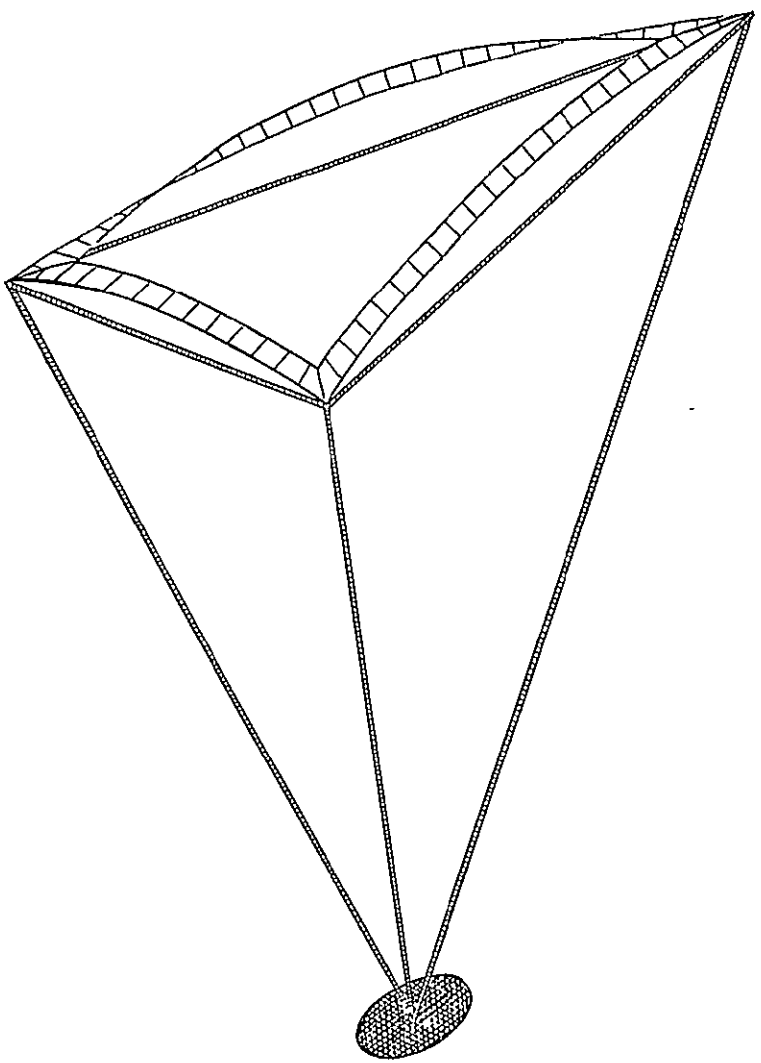
TEXTUROMETER — SYSTEM CONCEPT



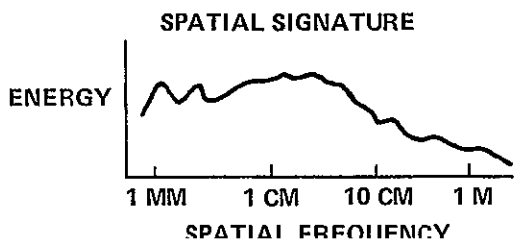
- MEASURES THE TEXTURE OF THE GROUND SURFACE AT SCALES FROM 1 MM TO 1M
- SPATIAL FREQUENCY WOULD ASSIST IN CLASSIFICATION OF GROUND MATERIALS - METHOD CURRENTLY NOT PURSUED

METHOD 1

- VISIBLE/IR LASER USED AS A SCATTEROMETER — PULSES RANGE GATED TO ACHIEVE SPATIAL FREQUENCIES
- STATISTICAL MEASURE OF GROUND PERIODICITY IS THE DESIRED OUTPUT

METHOD 2

- VARIATION IN REFLECTANCE IN THREE DIRECTIONS (60° APART) PROVIDES A POINT SAMPLE OF TEXTURE
- THREE LINES OF MIRRORS, EACH CONTAINING ADAPTIVE OPTICS, PROVIDE THE MEASUREMENTS
- COMPLEX DATA PROCESSING IS REQUIRED TO TRANSFORM THE DATA TO SPATIAL FREQUENCY DISTRIBUTION
- ATMOSPHERIC SCATTERING MAY LIMIT RESOLUTION



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TEXTUROMETER — SYSTEM CONCEPT (CONTINUED)

PLACE NASA

PERFORMANCE PARAMETERS

- USE EITHER CO2 (9-11 μm) OR Nd/YAG (1.064 μm)
- REQUIRES PICOSECOND PULSES
- DATA RATE — 25 SAMPLES - 90 KBPS
- EACH LINE OF MIRRORS CONTAINS 100 MIRRORS, EACH 3.0 METERS SQUARE
- ORBIT IS 600 KM CIRCULAR
- OPTICAL SPECTRUM: VISIBLE THROUGH IR
- ADAPTIVE OPTICS AND IMAGE MOTION COMPENSATION REQUIRED
- MIRROR FOCAL LENGTH $\approx$ 600 M, MIRROR LINE LENGTH 300 M

SYSTEM CONSIDERATIONS

MISSIONS CONTRIBUTED TO:
IDENTIFICATION OF VEGETATION,
MEASUREMENT OF PARTICLE SIZE,
GROUND PERIODICITY

RELATED SPACECRAFT: SWEEP FREQUENCY RADAR

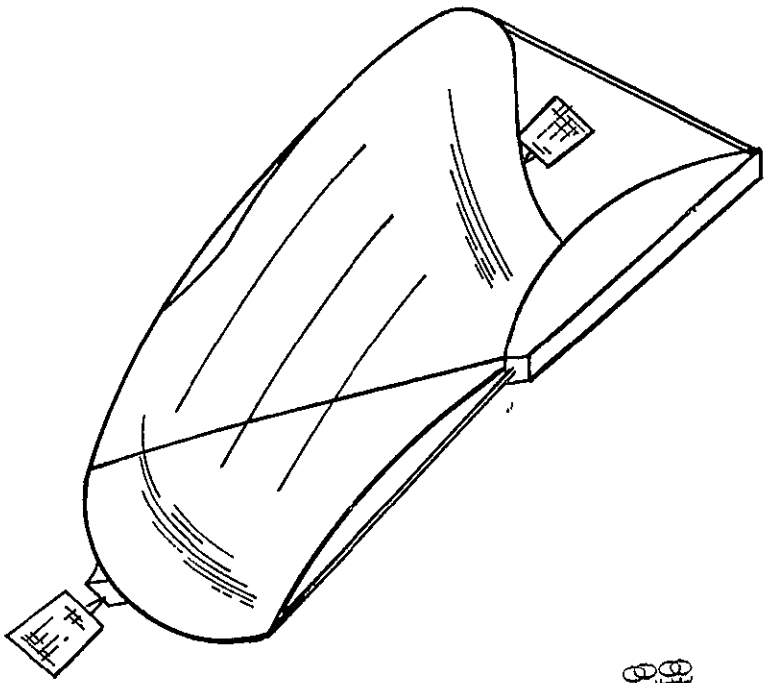
TIME PROJECTION: 1995

MEASURE OF RISK: HIGH

SPACE DIVISION

MICROSAT – SYSTEM CONCEPT

PLACE NASA



- L-BAND PASSIVE RADIOMETER
- PARABOLIC TORUS ANTENNA WITH CLUSTER OF FEED HORNS IN A FOCAL ARC
- WOULD REQUIRE PREVIOUS COMMITMENT TOWARD LARGE STRUCTURES IN SPACE

SPACE DIVISION

MICROSAT — SYSTEM CONCEPT (CONTINUED)

PLACE NASA

PERFORMANCE PARAMETERS

- FREQUENCY IS 1.4 GHZ (L BAND)
- ANTENNA SIZE APPROXIMATELY 600M X 1300M
- GROUND RESOLUTION — 1KM, ORBIT — 1000KM, REPEAT CYCLE — 3 DAYS (2 SPACECRAFT), RADIOMETRIC TEMP. RES. — $1^{o}K$
- DATA RATE (PEAK) — 59 KBPS

SYSTEM CONSIDERATIONS

OBJECTIVE CONTRIBUTED TO:
SOIL MOISTURE

RELATED SPACECRAFT:
ALL MICROWAVE SYSTEMS
EXCEPT TEXTURE SYSTEMS

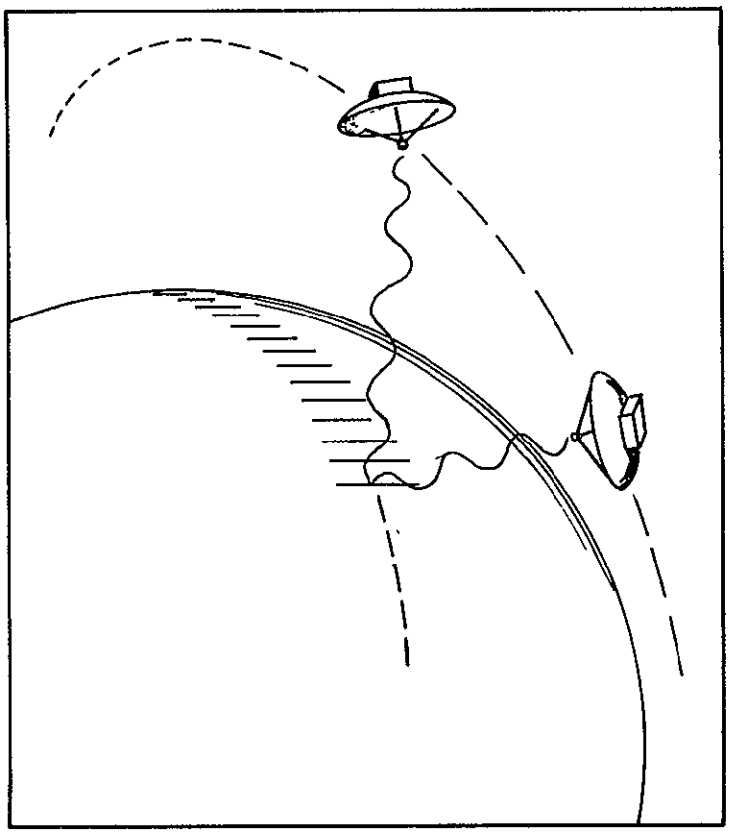
TIME PROJECTION: 1988-1992

MEASURE OF RISK: MEDIUM

SPACE DIVISION

RADAR ELLIPSOMETER — SYSTEM CONCEPT

PLACE NASA



- BASED ON EARLY WORK BY SIEGFRIED AUER
- BISTATIC RADAR APPROACH EMPLOYS ONE SPACECRAFT FOR TRANSMITTER AND ONE FOR RECEIVER (SPECULAR REFLECTION ONLY)
- SYSTEM WILL MAP DIELECTRIC CONSTANT OF THE SOIL, DIELECTRIC CONSTANT OF VEGETATION, AND HEIGHT OF VEGETATION
- MEASURES EFFECT OF REFLECTION ON POLARIZATION OF PLANE POLARIZED WAVES (3 MEASUREMENTS OF ELLIPTICITY)
- ONE PROBLEM AREA APPEARS TO BE THE FARADAY ROTATION THROUGH THE IONOSPHERE

SPACE DIVISION

RADAR ELLIPSOMETER — SYSTEM CONCEPT (CONTINUED)

PLACE NASA

PERFORMANCE PARAMETERS

- FREQUENCY — 300 MHZ
- GROUND RESOLUTION — 100 M
- DATA RATE — 2.65 MBPS
- SWATH WIDTH — 160 KM
- ALTITUDE — 600 KM (NOMINAL)

SYSTEM CONSIDERATIONS

OBJECTIVES CONTRIBUTED TO:

SOIL MOISTURE,
VEGETATION HEIGHT,
VEGETATION CLASSIFICATION,
VEGETATION MOISTURE CONTENT

RELATED SPACECRAFT: ALL

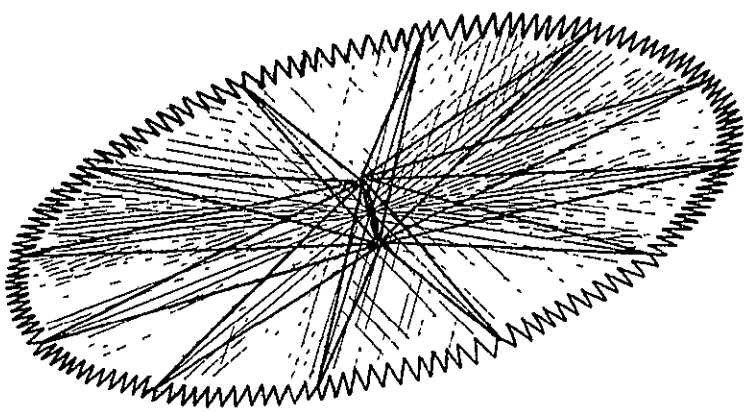
TIME PROJECTION: 1995

MEASURE OF RISK: HIGH

SPACE DIVISION

FERRIS WHEEL RADAR — SYSTEM CONCEPT

PLACE NASA



- LARGE (30 KM DIAMETER) ROTATING CABLE STRUCTURE THAT RELIES ON CABLE TENSION FOR SUPPORT. PRESUMES PREVIOUS COMMITMENT TO ASSEMBLY OF LARGE STRUCTURES IN SPACE
- REAL APERTURE RADAR OPERATES AT LOW FREQUENCY (30-300 MHZ) FOR GROUND PENETRATION
- RESULTANT RETURN SIGNAL CAN MAP MATERIALS (BOUNDARY LAYERS AND GROUNDWATER) TO AN AVERAGE DEPTH OF 75 M
- SPACECRAFT SPIN VECTOR IS FIXED IN INERTIAL SPACE
- PROBLEM AREA TO BE EXAMINED IS THE ATTENUATION EFFECTS OF THE IONOSPHERE.
- IC CHIPS FORM ELEMENTS OF A RANDOM SPARSE PHASED ARRAY
- TRADE BETWEEN CW AND PULSED IMPLEMENTATION YET TO BE PERFORMED

SPACE DIVISION

FERRIS WHEEL RADAR — SYSTEM CONCEPT (CONTINUED)

PLACE NASA

PERFORMANCE PARAMETERS

- 30 KM DIAMETER
- 75 M DEPTH
- 300 M GROUND RESOLUTION
- VERTICAL TARGET RESOLUTION BELOW GROUND SURFACE — APPROXIMATELY 2M
- FREQUENCY — 30-300 MHZ
- SPIN RATE APPROXIMATELY 1 REV/HR
- 900 KM ORBIT

SYSTEM CONSIDERATIONS

MISSIONS CONTRIBUTED TO:
- GEOLOGIC RESOURCES LOCATION
- GROUNDWATER MAPPING
- SOIL MOISTURE

COMPETING SPACECRAFT: NONE

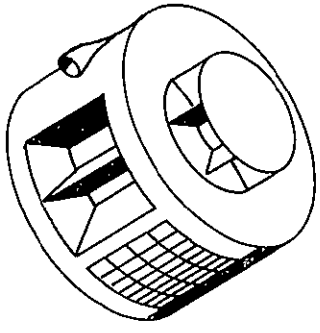
TIME PROJECTION: 1995-2000

MEASURE OF RISK: HIGH

SPACE DIVISION

SATCLOUD — SYSTEM CONCEPT

PLACE NASA



- CONCEPT OF BUILDING A SMALL (20 IN.)^3, CHEAP (K$), LIGHT (MOSTLY PLASTIC) DAUGHTER SPACECRAFT
- LAUNCH MANY (10^3 - 10^4) IN A GEOSYNCHRONOUS ORBIT TO PROVIDE A REAL APERTURE RADAR
- WOULD REQUIRE MOTHER SATELLITE FOR STATION-KEEPING, COMMAND AND CONTROL
- MANY POTENTIAL PROBLEMS IN DEPLOYMENT, SURVEILLANCE, TIMING
- BASED ON SPARSE PHASED ARRAY SYSTEM
- TWO MODE OPERATION WOULD ALLOW FOR VARIABLE RESOLUTION AND SWATH WIDTH
- ALTERNATIVE APPLICATION IN RADAR HOLOGRAPHER SYSTEM CONCEPT (NOT PRESENTED)

SPACE DIVISION

SATCLOUD — SYSTEM CONCEPT (CONTINUED)

PLACE NASA

PERFORMANCE PARAMETERS

- FREQUENCY — 3 GHZ
- CONSTELLATION — 10^4 SPACECRAFT
  — 100 KM DIAMETER ARRAY
- SWATH WIDTH — 100M/75KM
- GROUND RESOLUTION — 1M/100M

SYSTEM CONSIDERATIONS

MISSIONS CONTRIBUTED TO: ALL

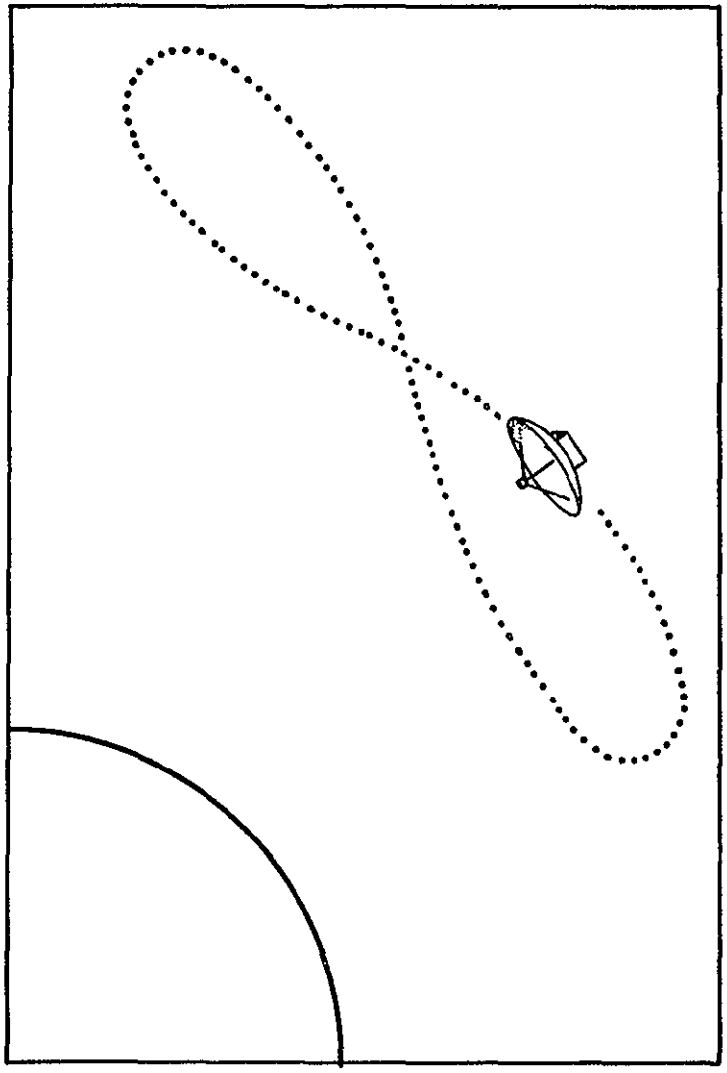
RELATED SPACECRAFT: LANDSAT H
EARTHWATCH
GEOSYNCHRONOUS SAR

TIME PROJECTION: 1995-1997

MEASURE OF RISK: HIGH

SPACE DIVISION

GEOSYNCHRONOUS SAR — SYSTEM CONCEPT



- SYSTEM USES THE NORTH-SOUTH DRIFT OF A GEOSYNCHRONOUS SPACECRAFT TO PROVIDE THE RANGE-RATE FOR A SYNTHETIC APERTURE
- THE SYSTEM MAPS FOOTPRINTS OF THE EARTH BY STARING AT THEM (INTEGRATING) FOR ABOUT 8 MINUTES
- TYPICAL ELEVATION ANGLES OF 30^{o} - 60^{o}
- APPROXIMATE TIME TO MAP THE ENTIRE U.S. IS 4-1/2 HRS.
- POTENTIAL PROBLEMS IN DATA STORAGE (10^{12} BITS), PROCESSING AND OSCILLATOR STABILITY

SPACE DIVISION

GEOSYNCHRONOUS SAR — SYSTEM CONCEPT (CONTINUED)

PLACE NASA

PERFORMANCE PARAMETERS

- FREQUENCY = 2.5 GHZ - S-BAND
- FOOTPRINT SIZE = 1050 KM x 650 KM
- GROUND RESOLUTION - 100 M
- INTEGRATION TIME/FOOTPRINT — 8-12 MIN. MAP ENTIRE U.S. ~ 4.5 HRS. (~1.1B PIXELS)
- AVERAGE RF POWER = 800 W
- ANTENNA SIZE — 7.3 M DIAMETER
- ORBIT INCLINATION ANGLE — 1^{o}

SYSTEM CONSIDERATIONS

MISSIONS CONTRIBUTED TO: ALL

RELATED SPACECRAFT:

- LANDSAT
- EARTHWATCH
- SAT CLOUD
- RADAR HOLOGRAPHER

TIME PROJECTION: 1987 - 1990

MEASURE OF RISK: LOW

SPACE DIVISION

AGENDA

INTRODUCTION

MISSION OBJECTIVES AND REQUIREMENTS

SYSTEM ELEMENTS

SYSTEM CONCEPTS

➡ TECHNOLOGY REQUIREMENTS AND FORECASTING

PRIORITY ANALYSIS

SPACE DIVISION

SPACE TRANSPORTATION PROSPECTS/COSTS
(1985–2000)

PLACE NASA

ELEMENTS

OPTIONS

- EARTH TO LEO
  - SHUTTLE
  - SUPER-SHUTTLE
  - HLLV
- LEO TO HIGH LEO (1000 KM)
  - SPACE TAXI
  - SELF PROPELLED
    - CHEMICAL
    - ELECTRICAL
- LEO TO GEO
  - SSUS
  - IUS
  - "TUG"
  - AEROTUG
  - SEPS

OPINIONS

SHUTTLE 'TIL 1992
$500 - 1000/KG

SUPER SHUTTLE
$50 - 100/KG
AMORTIZATION DOMINATES

CHEMICAL SELF-PROPELLED

EARLY SOLID
~$3000-8000/KG

FROM LATE 80's ON – SEPS
$1000 - 2000/KG (EARLY)

SPACE DIVISION

PLACE FAMILY ORBITS

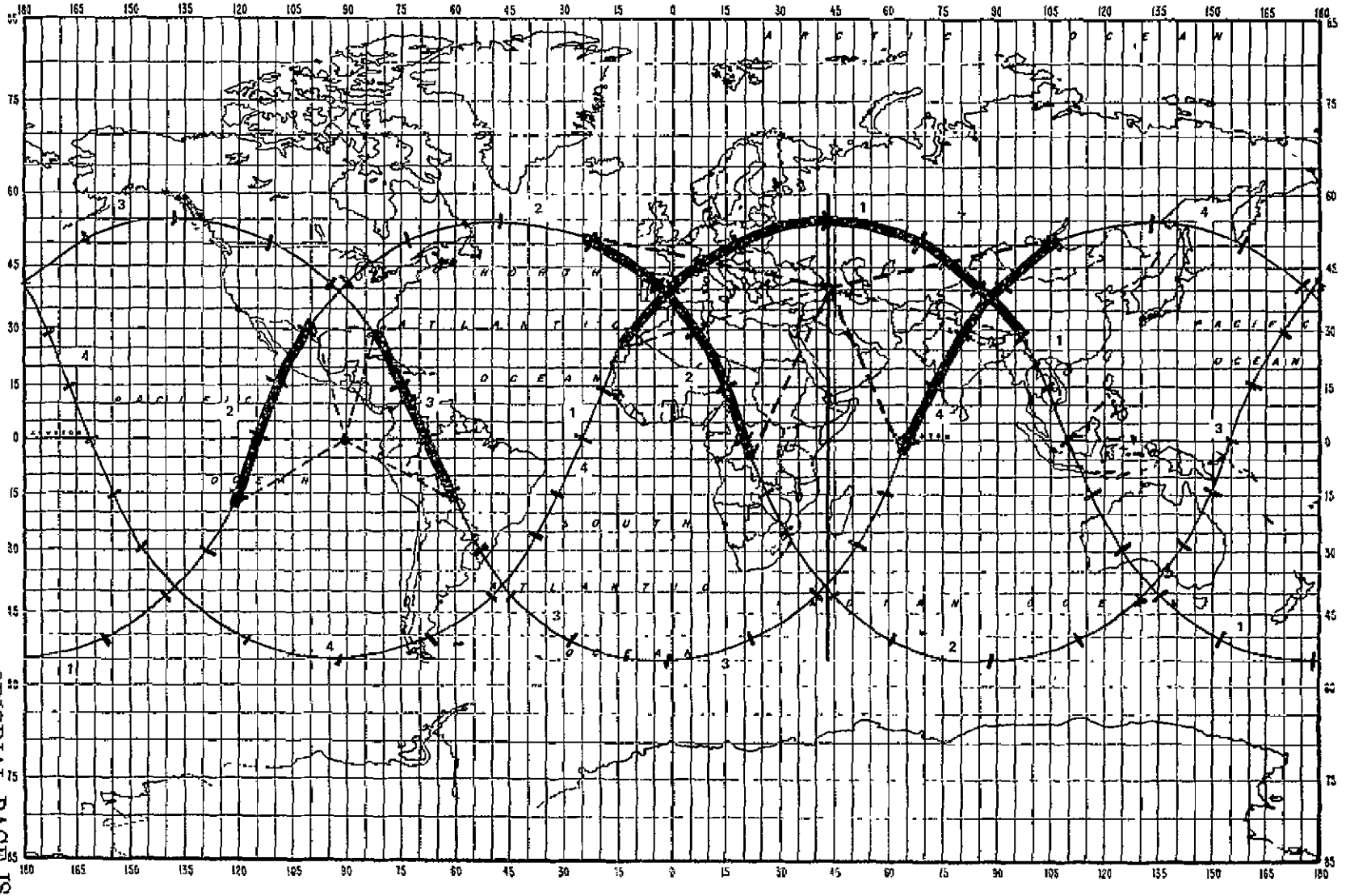
PLACE NASA

- SPACE SHUTTLE SORTIE
- LANDSAT CLASS – SUN SYNCHRONOUS
- EARTH WATCH
- 24 HOUR ORBITS

SPACE DIVISION

EARTHWATCH — INCLINED REPEATING ORBITS

PLACE



SPACE DIVISION

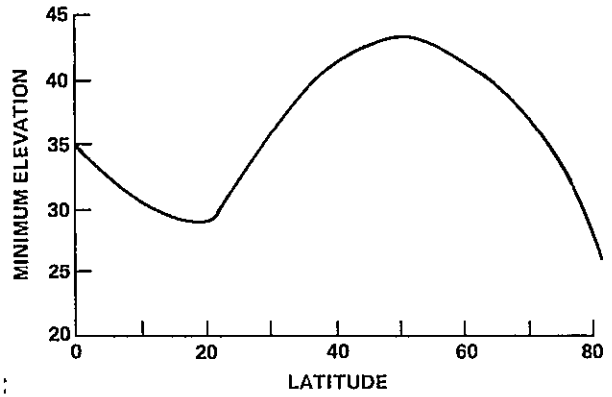
EARTHWATCH VIEWING CONDITIONS

PLACE NASA

VISIBILITY -- MINUTES				
LATITUDE	ELEVATION	ORBIT NO. 1	ORBIT NO. 2	ORBIT NO. 4
~ 0	10	96	130	130
	20	0	104	104
	30	0	81	81
	40	0	60	60
20	10	142	120	120
	20	106	96	96
	30	64	70	70
	40	0	42	42
30	10	143	115	115
	20	114	90	90
	30	87	62	62
	40	59	32	32

CASE

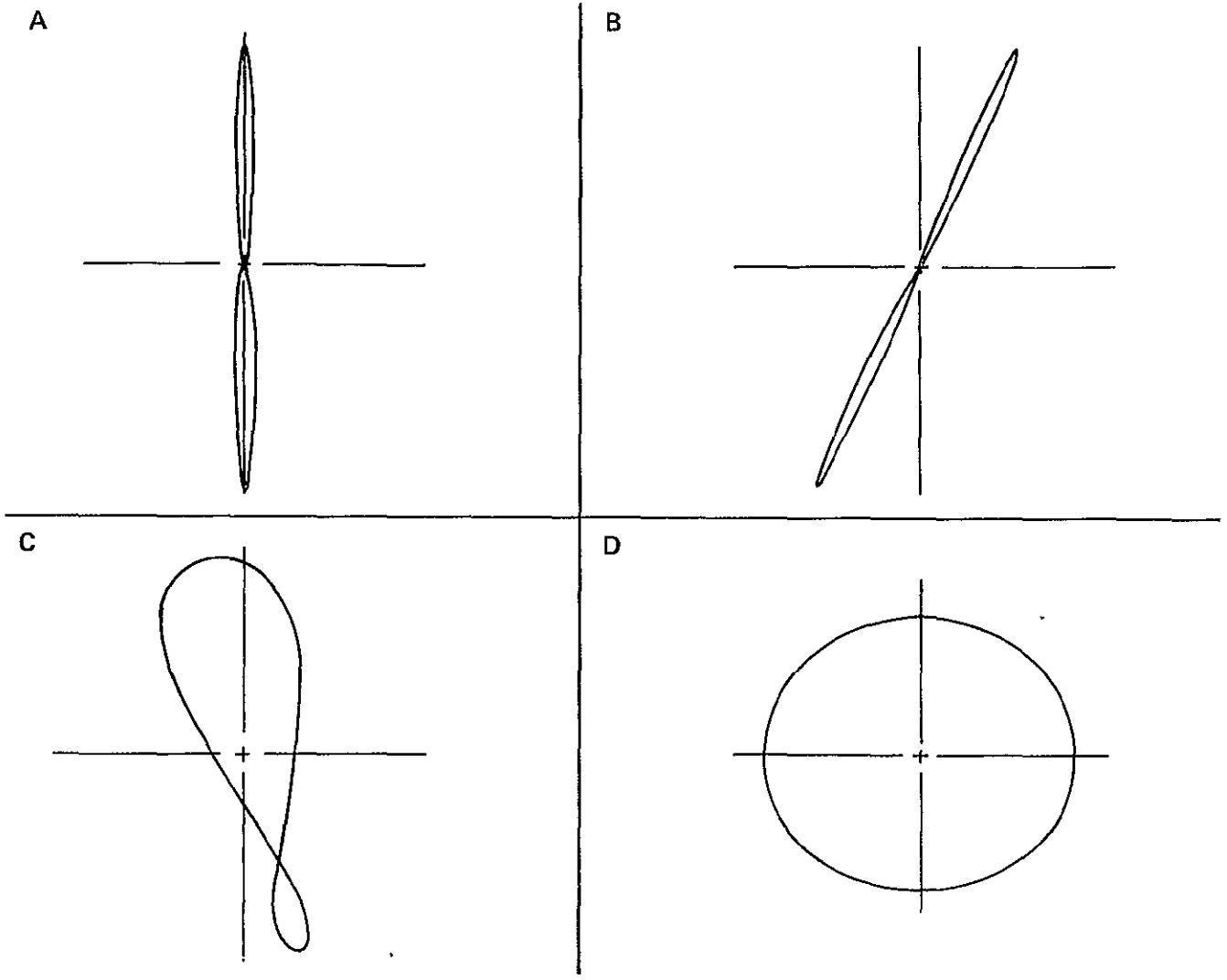
PERIOD: 6 HOURS
SATELLITES: 20
REPEAT GRD TRACKS: ONE



SPACE DIVISION

VARIATIONS ON THE 24-HOUR ORBIT

PLACE NASA



SPACE DIVISION

EXPLORATORY PLATFORM CONCEPTS

- LARGE STRUCTURES
  - LARGE STRUCTURE DEVELOPMENT (E.G., BEAM BUILDERS)
  - UV POLYMERIZED STRUCTURES
- MULTIPLE SATELLITES → SATELLITE SWARM
- LOW COST DEVELOPMENTS → SATELLITE SWARM
  - MICROCIRCUITS
  - SOLAR CELLS
- MULTIPLE SATELLITES → "IMPOSSIBLE ORBITS"
- ELECTRIC PROPULSION → "IMPOSSIBLE ORBITS"
  - LOW COST HIGH ORBITS
  - SEPS "SORTIE" MISSIONS

SPACE DIVISION

POWER SUB-SYSTEM TRADE STUDY
(MULTI-KILOWATT SYSTEMS)

PLACE NASA

ELEMENTS

OPTIONS	OPINIONS
• POWER SOURCE	
— SOLAR ARRAY	ORIENTED — CONCENTRATED
• ORIENTED OR FIXED	PROBABLY GaAs
• CENTRAL OR DISPERSED	— RADIATION RESISTANT
— SOLAR DYNAMIC	
— ISOTOPES	
• POWER STORAGE	
— ADVANCED BATTERIES	CLOSE
— FUEL CELLS	PROBABLY BATTERIES
— FLY WHEELS	200-300 WHR/KG
— OTHER	50% + DOD
• DISTRIBUTION	
— AC VS DC	
— 28V OR HIGHER	28V DC

SPACE DIVISION

NAVIGATION, CONTROL AND PROPULSION
(PRELIMINARY)

PLACE

ELEMENTS

OPTIONS	OPINIONS
• TORQUER — REACTION WHEELS — JETS (ION/PLASMA)	REACTION WHEELS IN LEO HIGH ORBIT?
• ATTITUDE SENSORS — SUN — HORIZON — STAR — INERTIAL — MONOPULSE	ADVANCED INERTIAL — STAR — MONOPULSE
• EPHEMERIS — GPS — RADIO TRILATERATION — LASER TRACKING	TRILATERATION PLUS ON-BOARD MODELING
• PROCESSING — SHARED CENTRAL — DEDICATED — DISPERSED	DEDICATED LSI (EACH SENSOR/TORQUER CLUSTER)

SPACE DIVISION

EXPLORATORY SENSING CONCEPTS

PLACE

- TEXTURE DISCRIMINATION
  - WIDE BAND SWEEP RADAR
    - PLANT WIND-RESPONSE SCATTEROMETER
  - OPTICAL TEXTURE
- GEOSYNCHRONOUS SAR
- LASER ATMOSPHERE CALIBRATOR
- MICROWAVE HOLOGRAPHY
- LONG BASELINE INTERFEROMETRY
  - MULTIPLE SATELLITES
  - MULTITUDE OF SATELLITES
- GRAVITY/MAGNETIC FIELD SENSING
  - TETHER SATELLITE
  - FARADAY ROTATION MAGNETOMETER

SPACE DIVISION

THE TDRS SYSTEM

PLACE NASA

TDRS I — 80-81 LAUNCH

- 2 SPACECRAFT — 1 GROUND STATION
- S-BAND (S/C TO GROUND) — 12 MBPS MAX. (GROUND TO S/C) - 300 KBPS
- K-BAND (S/C TO GROUND) - 300 MBPS MAX., 50 MBPS TYPICAL
  (GROUND TO S/C) - 25 MBPS

TDRS II — POST '90 LAUNCH

- ON-BOARD STORAGE AND BANDWIDTH REDUCTION PROCESSING
  - CALL-UP AND RETRIEVAL OF SAMPLED DATA
  - 10^7 MEGABIT MEMORY, (5-50 BIT COMPRESSION RATIOS)
- GROUND DATA STORAGE AND PROCESSING AVAILABLE
- SPACECRAFT TO GROUND LINK
  - S-BAND - 20 MBPS
  - K-BAND - 300 MBPS
  - MMW - 1 GBPS
- SPACECRAFT TO SPACECRAFT LINK
  - MMW - 500 MBPS
  - LASER - 3 GBPS
- GROUND TO TDRS TO USER SPACECRAFT
  - S-BAND - 12 MBPS
  - K-BAND - 100 MBPS
  - MMW - 500 MBPS

SPACE DIVISION

FUTURE COMMUNICATIONS OPPORTUNITIES

PROJECTED MILLIMETER WAVE (MMW) DATA LINKS

- FREQUENCY — 20-40 GHZ
- PROJECTED PARAMETERS — 10 WATTS (TWT), 30% EFFICIENT, 1 KG WEIGHT
  UNCOOLED PARAMP (SPACE) -80°K — COOLED (17°K)
  PARAMP (GROUND) -15°K
- PROJECTED MMW LINK DATA RATES — 1 GIGABIT/SEC FROM SPACECRAFT
  500 MEGABITS/SEC TO SPACECRAFT

PROJECTED LASER DATA LINKS

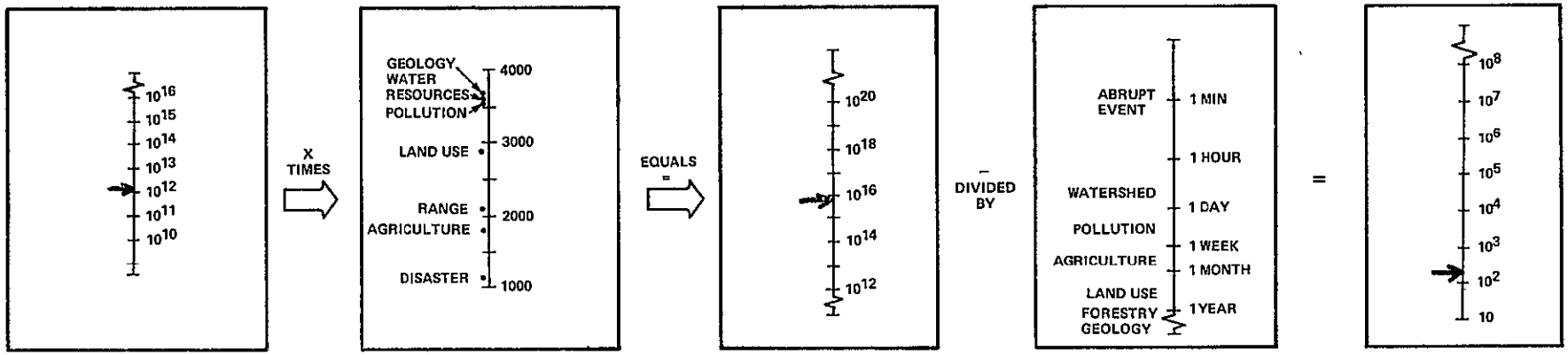
- CANDIDATES — NEODYNIUM GLASS (Nd/YAG - 1.064 μm) AND
  CARBON DIOXIDE (CO_2 - 9 TO 11 μm)
- PROJECTED PARAMETERS:

Nd/YAG	CO_2
0.8W, 10% EFF.	10 W, 15% EFF.
40 CM TRANSMIT OPTICS	25 CM TRANSMIT OPTICS
60 CM RECEIVE OPTICS	25 CM RECEIVE OPTICS
9×10^7 M RANGE (IN SPACE)	7.4×10^7 M RANGE (IN SPACE)
0.2 M^3 SIZE	0.7 M^3 SIZE
2 KG WEIGHT	75 KG WEIGHT
SOLID-STATE SYSTEM	SEALED-OFF GAS SYSTEM

- PROJECTED 2-WAY LINK DATA RATES — 3 GIGABITS/SEC

SPACE DIVISION

COMPUTATIONAL POWER REQUIREMENTS



TOTAL VOLUME OF INPUT DATA (BYTES) TO BE PROCESSED PER MISSION PER PROCESS CYCLE

NUMBER OF PROCESSES PER BYTE OF INPUT DATA

PROCESSES PER MISSION PER PROCESS CYCLE

TURNAROUND TIME

MEGA OPS PER SECOND (24 HR, 7 DAY FACILITY UTILIZATION)

SPACE DIVISION

EXAMPLES OF EXTRACTIVE PROCESSING REQUIREMENTS

PLACE NASA

	CROP PRODUCTION	WATERSHED MONITORING	GEOLOGY	DISASTER ASSESSMENT
AREA IN 10^6M^2	5.9×10^6	$.188$ (U.S.) $\times 10^6$	59×10^6	510×10^6
SAMPLING STRATEGY	1	1	1	10^{-6}
PIXELS IN 10^6M^2 (30 METER)	10^3	10^3	10^3	10^3
NO. OF SPECTRAL CHANNELS	10	10	10	10
NO. OF LOOKS	1	1	2	2
SUM + ANCILLARY EQUIVALENT	2	2	1	1
BYTES	1.2×10^{11}	4×10^9	1.2×10^{12}	10^{13}
OPERATIONS PER BYTE	1.8×10^3	3.8×10^3	3.7×10^3	1.1×10^3
TOTAL OPERATIONS	2.2×10^{14}	3.7×10^{12}	8.1×10^{15}	1.1×10^{10}
÷ TURNAROUND TIME	1.2×10^6 (2 WK.)	8.6×10^4 (1 DAY)	3.15×10^7 (1 YR.)	600 (10 MIN.)
MOPS/SEC	180	43	260	18

SPACE DIVISION

EXPLORATORY DATA SYSTEM CONCEPTS

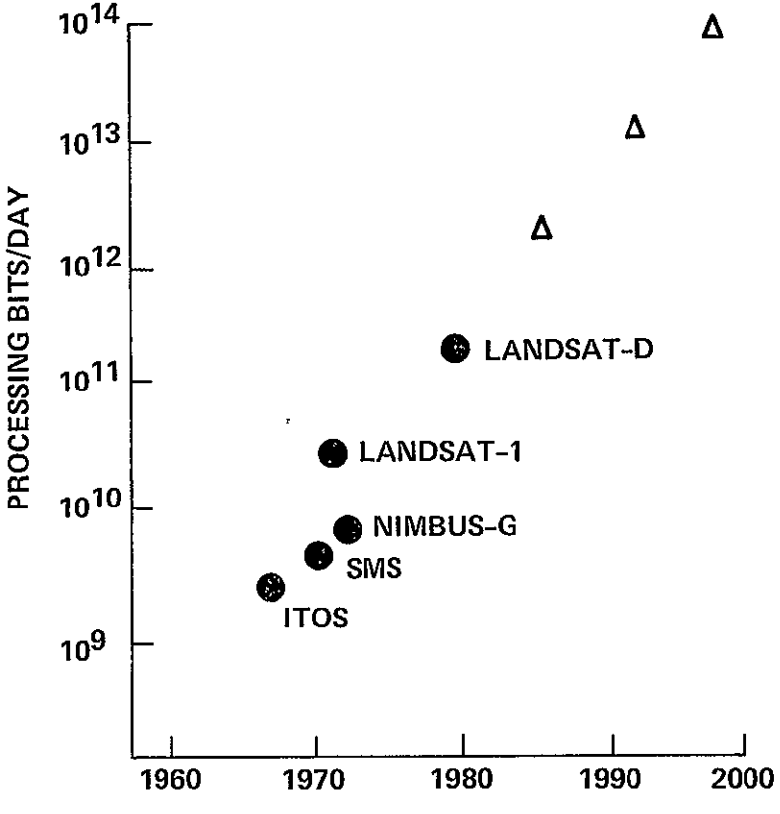
- MICROCIRCUITS
  - SILICON
    - SIZE, COST, SPEED — NO END IN SIGHT
  - MULTIFUNCTION CHIPS
    - SENSE, PROCESS (CID IMAGE, HADAMARD TRANSFORM)
    - LOGIC IN MEMORY
  - LITHIUM NIOBATE/SILICON
    - ACOUSTICAL, OPTICAL, ELECTRONIC
  - GaAs
    - IR SENSE/PROCESS
    - FASTER
- LARGE DATA BASE STORAGE
- LARGE DATA BASE MANAGEMENT
  - REAL TIME EXTRACTION; STORE ESSENTIALS ONLY
  - ARTIFICIAL INTELLIGENCE; INTERACTIVE LANGUAGES
  - SOPHISTICATED INDEXING
- OPTICAL PROCESSING

SPACE DIVISION

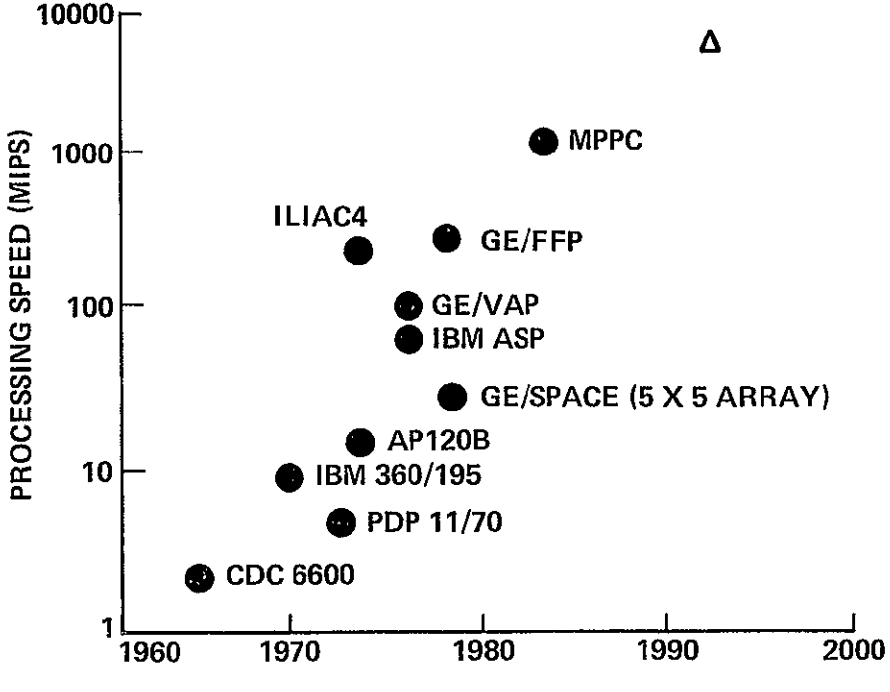
THE DATA PROCESSING EXPLOSION

PLACE NASA

DATA PROCESSING REQUIREMENTS

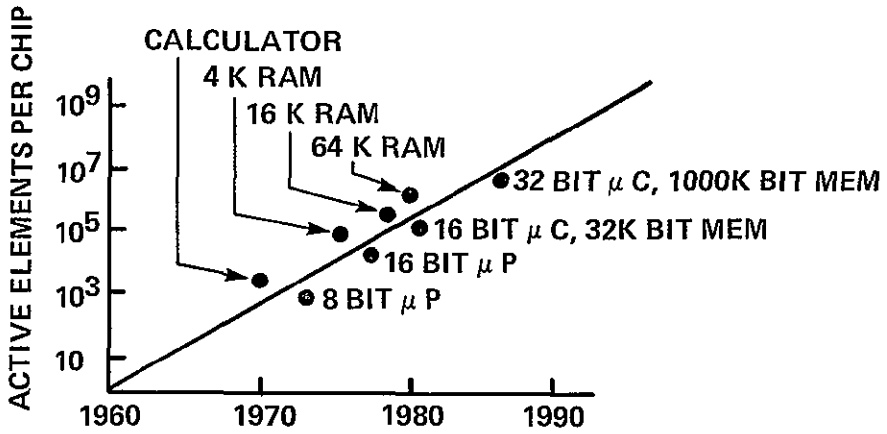


DATA PROCESSING CAPABILITIES

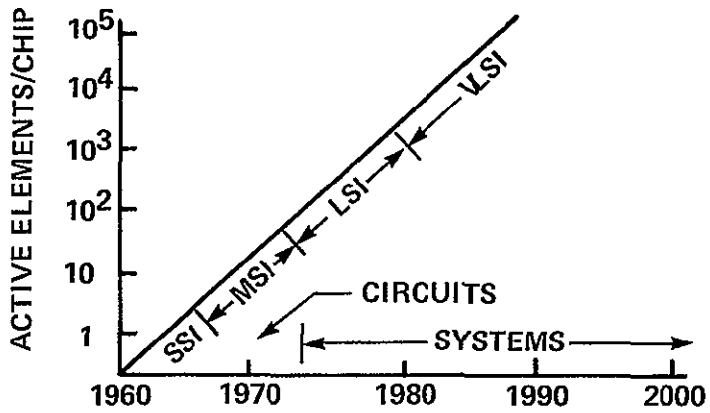


SPACE DIVISION

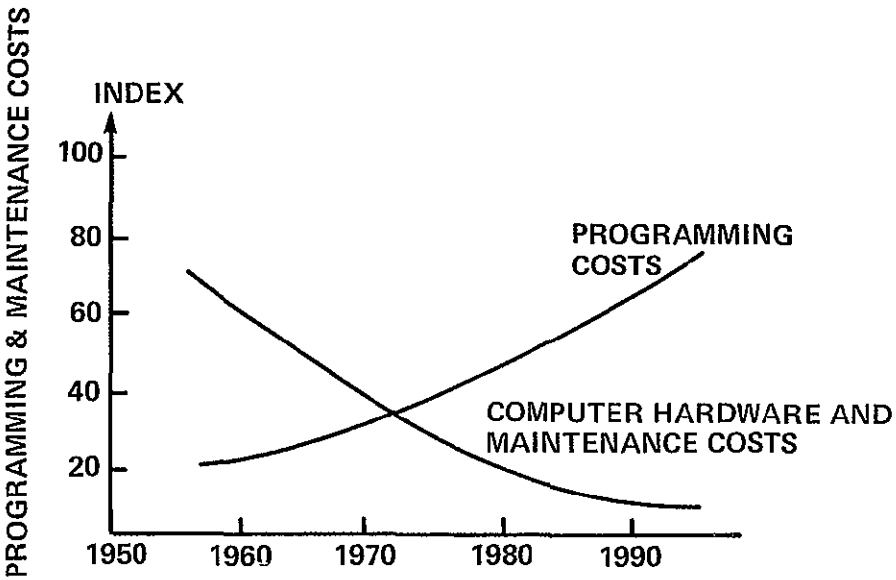
NEW DIRECTIONS IN TECHNOLOGY



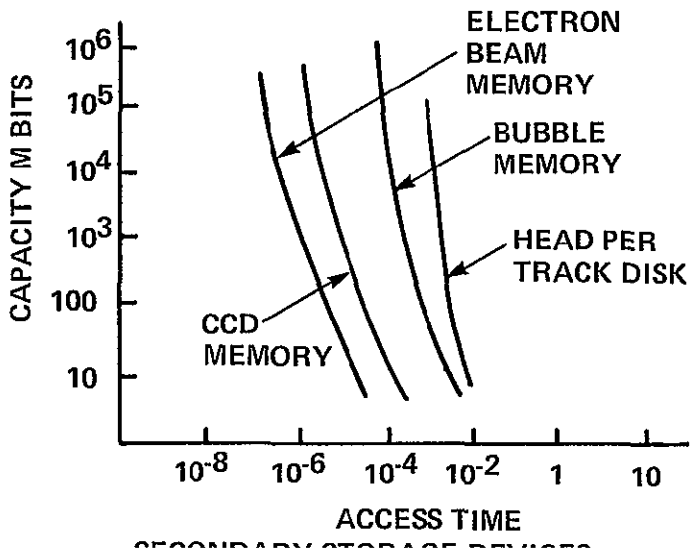
SEMICONDUCTOR CHIP COMPLEXITY



DISTRIBUTED SEMICONDUCTOR POWER



NET COST OF PROGRAM DEVELOPMENT



ACCESS TIME

SPACE DIVISION

ON-BOARD PROCESSING — THE NEED FOR LESS DATA

PLACE NASA

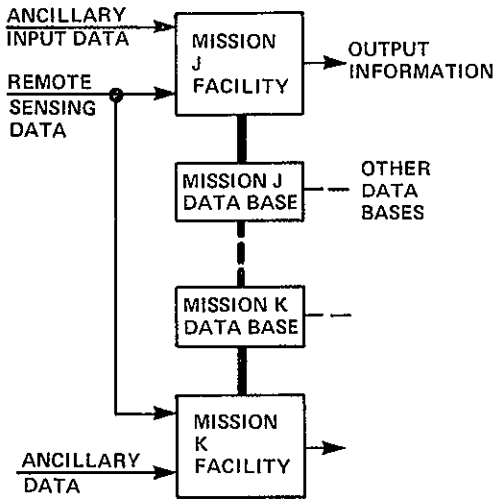
- RADIOMETRIC CORRECTION
- GEOMETRIC CORRECTION
  - USE REAL TIME EPHEMERIS/ATTITUDE DATA
  - RESAMPLING USING AN OVERSAMPLED DETECTOR ARRAY
- IMAGE SELECTION
  - CLOUD COVER DETECTION — 3 SPECTRAL BANDS, LOW NUMBER OF SCENE SAMPLES
  - HAZE DETECTION — USE HISTOGRAM COMPARISONS/ACTIVE MEASUREMENTS
- CHANGE DETECTION
  - PIXEL TO PIXEL COMPARISON
  - HISTOGRAM COMPARISON
  - CORRELATION (FFT)
  - THEME CHANGES/CLASSIFICATION
- DATA COMPRESSION

SPACE DIVISION

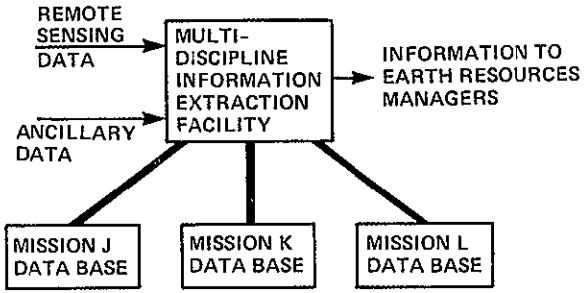
GLOBAL DATA BASE ALTERNATIVES

PLACE NASA

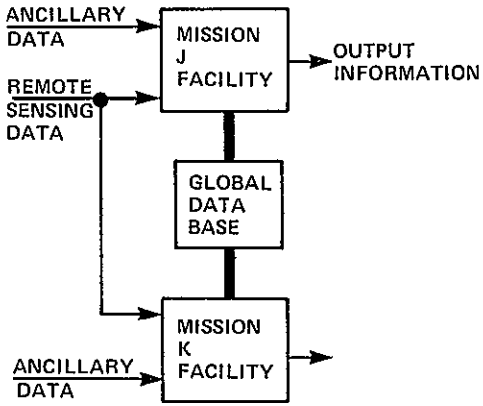
DISTRIBUTED ← → CENTRALIZED



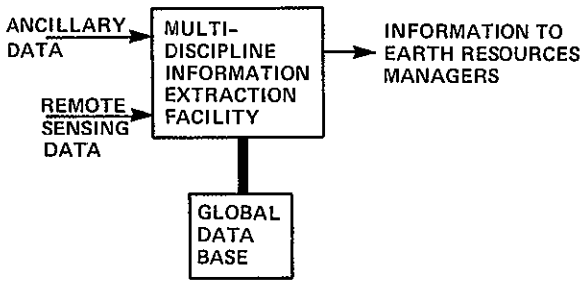
INDEPENDENT MISSION FACILITIES



INDEPENDENT DATA BASES



INTEGRATED DATA BASE



FULLY INTEGRATED SYSTEM

SPACE DIVISION

AGENDA

PLACE

NASA

INTRODUCTION

MISSION OBJECTIVES AND REQUIREMENTS

SYSTEM ELEMENTS

SYSTEM CONCEPTS

TECHNOLOGY REQUIREMENTS AND FORECASTING

➡ PRIORITY ANALYSIS

SPACE DIVISION

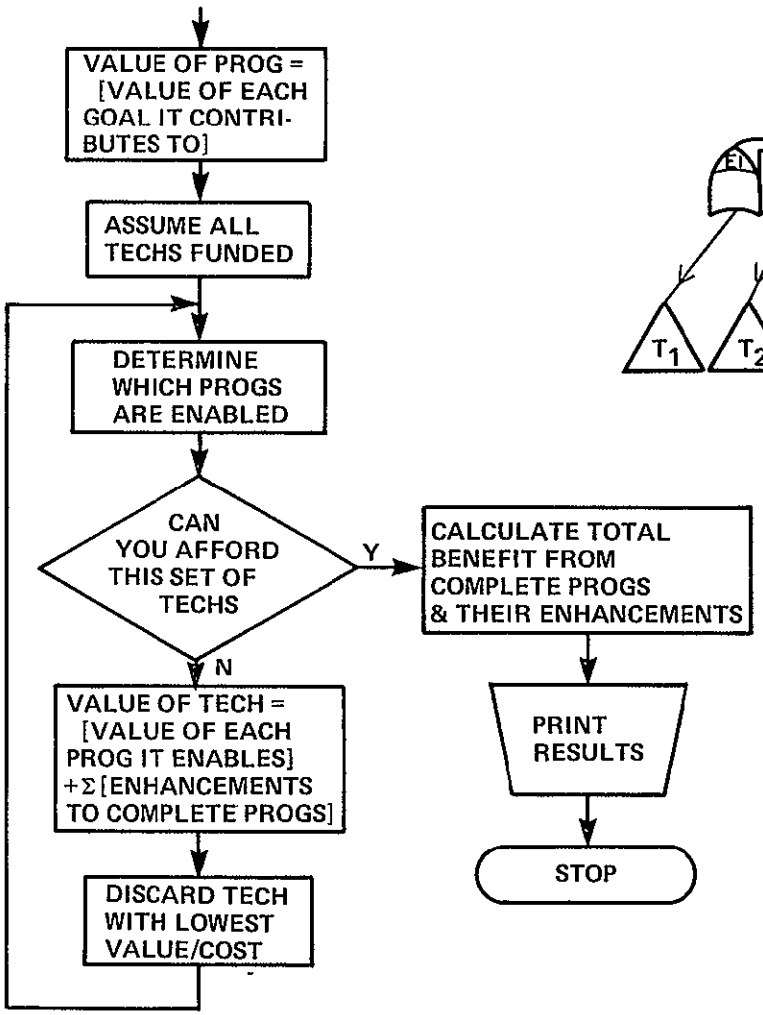
PRIORITY STRUCTURING METHODOLOGY

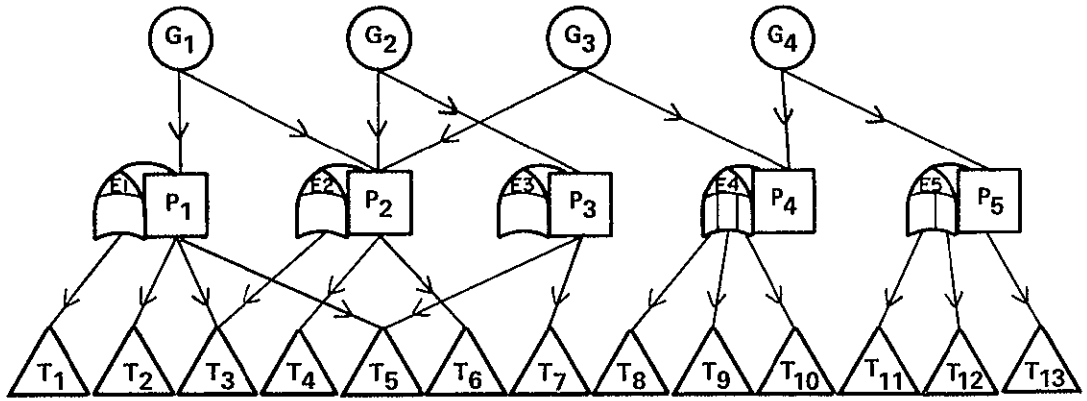
- GROUND RULES
  - TECHNOLOGIES SUPPORT PROGRAMS
  - ENHANCING TECHNOLOGIES JUST REDUCE IMPLEMENTATION COSTS
  - ENABLING TECHNOLOGIES MUST ALL BE FUNDED FOR THE PROGRAM TO BE COMPLETE
  - COMPLETED PROGRAMS CONTRIBUTE TO GOALS
  - GOALS MAY BE FULLY OR PARTIALLY MET
  - MEETING GOALS PRODUCES BENEFITS
- OBJECTIVE
  - ALLOCATE A GIVEN AMOUNT OF MONEY AMONG THE TECHNOLOGIES TO MAXIMIZE THE BENEFITS PRODUCED
- TWO METHODS
  - BOTTOM UP/GOODNESS MEASURE
  - TOP DOWN

SPACE DIVISION

TOP-DOWN METHOD

PLACE NASA





- ADVANTAGES
  - SHORT RUN TIME
  - CAN BE USED TO SIMPLIFY OR OBTAIN A STARTING POINT FOR BOTTOM-UP METHOD
- DISADVANTAGES
  - DOESN'T GUARANTEE TRUE GLOBAL OPTIMUM
  - WON'T SHOW WHICH OTHER COMBINATION OF TECHNOLOGIES ARE NEARLY AS GOOD

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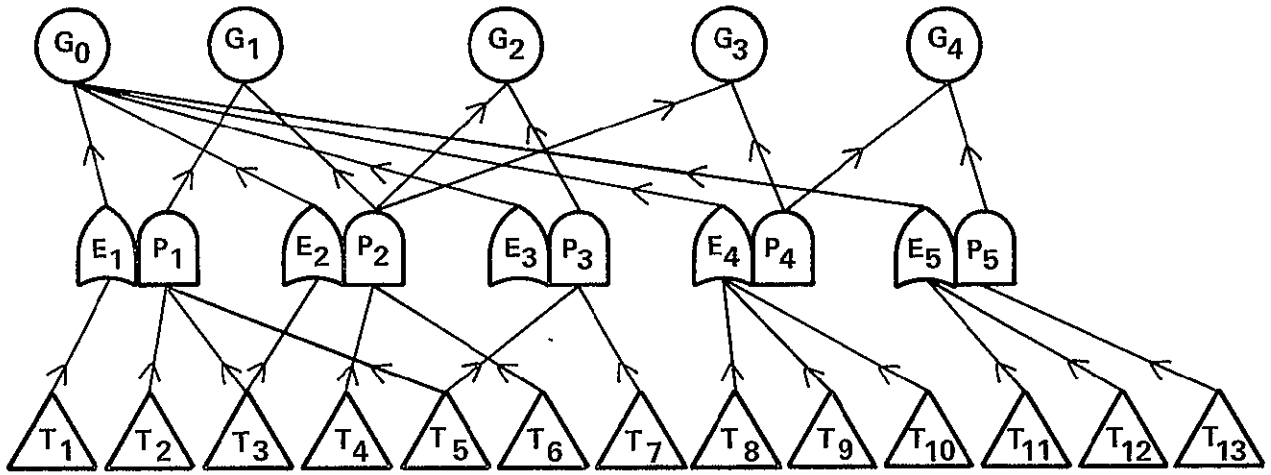
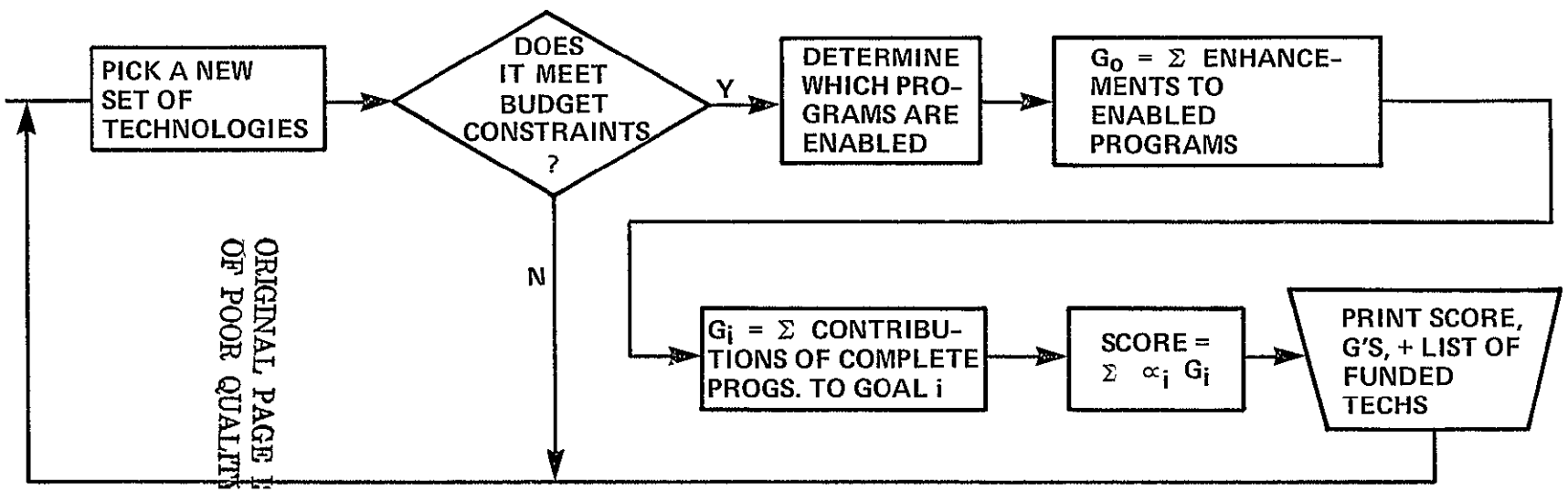
BOTTOM-UP METHOD

PLACE



- ADVANTAGES
  - THOROUGH
  - ALLOWS HUMAN DECISION MAKER TO EXAMINE ALL COMBINATIONS THAT ARE NEARLY AS GOOD AS THE BEST
- DISADVANTAGES
  - LONG RUN-TIME—IF THERE ARE MANY (> 20) TECHS IT IS IMPOSSIBLE TO EXAMINE EVERY CONTRIBUTION



SPACE DIVISION

FUTURE PLACE ACTIVITY

PLACE NASA

- MISSION ANALYSIS ACTIVITY,EXPLORATORY TECHNOLOGY FORECASTING, PRIORITY STRUCTURING METHODOLOGY ALL HAVE BEEN COMPLETED
- FUTURE SYSTEM CONCEPTS WITH RICH TECHNOLOGICAL CONTENT HAVE BEEN ESTABLISHED
- CHALLENGE TO THE PLACE TEAM IS TO REALIZE THE FULL "TECHNOLOGY REQUIREMENT POTENTIAL" OF THESE SYSTEM CONCEPTS
  - ACCURATE TECHNOLOGY REQUIREMENTS
  - WELL-BASED NORMATIVE TECHNOLOGY FORECASTING
  - INSIGHTFUL PRIORITY STRUCTURING AND DECISION SUPPORT

GENERAL ELECTRIC

Space Division / Headquarters Valley Forge, Pennsylvania ☐ Daytona Beach, Fla ☐ Cape Kennedy, Fla
☐ Evendale, Ohio ☐ Huntsville, Ala ☐ Bay St Louis, Miss ☐ Houston, Texas ☐ Newport Beach, Calif