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Shuttle Precursor Activity

Figure 1

64	65	66	67	68	69	70

SPACE STATION
- LARGE ORBITAL RESEARCH LABORATORY (300K)
- EXTENDED APOLLO (2459K)
- MANNED ORBITING RESEARCH LABORATORY (1500K)

SPACE STATION
SPACE BASE STUDIES
PHASE B
72

AD HOC SUBPANEL
REUSABLE LAUNCH
VEHICLE TECHNOLOGY
8/24/65 9/14/66

PRESIDENTS SPACE TASK GROUP
2/13/69 9/15/69

NASA SPACE SHUTTLE TASK GROUP
4/1/69 1/5/70

2/13/70
PROGRAM
OFFICE
JSC

SPACE LOGISTICS SYSTEMS
- MISSION REQUIREMENTS OF LIFTING SYSTEMS (500K)
- BALLISTIC ORBITAL SUPPORT (200K)
- REUSABLE LAUNCH VEHICLE SYSTEMS (547K)
- REUSABLE ORBITAL TRANSPORT (1.268K)
- LAUNCH VEHICLE COST STUDIES (472K)
  - REUSABLE AEROSPACE PASSENGER TRANSPORT (288K)
    - ADVANCED LOGISTIC SPACECRAFT (300K)
- NATIONAL SPACE BOOSTER (995K)
  - LOGISTIC SPACECRAFT EVOLVING FROM GEMINI (436K)
  - INTEGRATED LAUNCH AND REENTRY LOGISTICS SYSTEM (750K)

Shuttle Precursor Activity

STUDY CONCLUSIONS

- LATERAL RANGE CAPABILITY REDUCES OPERATIONS COSTS
- ABORT SURVIVABILITY CONSIDERATIONS MORE DIFFICULT FOR HIGH L/D CONFIGURATIONS
- HIGH L/D WEIGHT PENALTIES RELATIVE TO BALLISTIC CONFIGURATION DIMINISH WITH INCREASED CREW AND PAYLOAD SIZE
- LAND LANDING FOR BALLISTIC SYSTEMS — GLIDING PARACHUTES (L/D >2.0) IS FEASIBLE
- TWO STAGE FULLY REUSABLE 'AIR TRANSPORT' TYPE SYSTEMS HAVE VERY HIGH DDT&E COST, HIGH DEVELOPMENT RISK, SIGNIFICANT TECHNOLOGY GAPS
  - OPERATIONS COSTS HIGHLY SENSITIVE TO REFURBISHMENT
  - HIGH ANNUAL LAUNCH RATES REQUIRED TO AMORTIZE DDT&E
- VERTICAL TAKE OFF MOST EFFICIENT; LEAST COSTLY
- COST OF OWNERSHIP SENSITIVE TO FLIGHT RATE, DEGREE OF REFURBISHMENT

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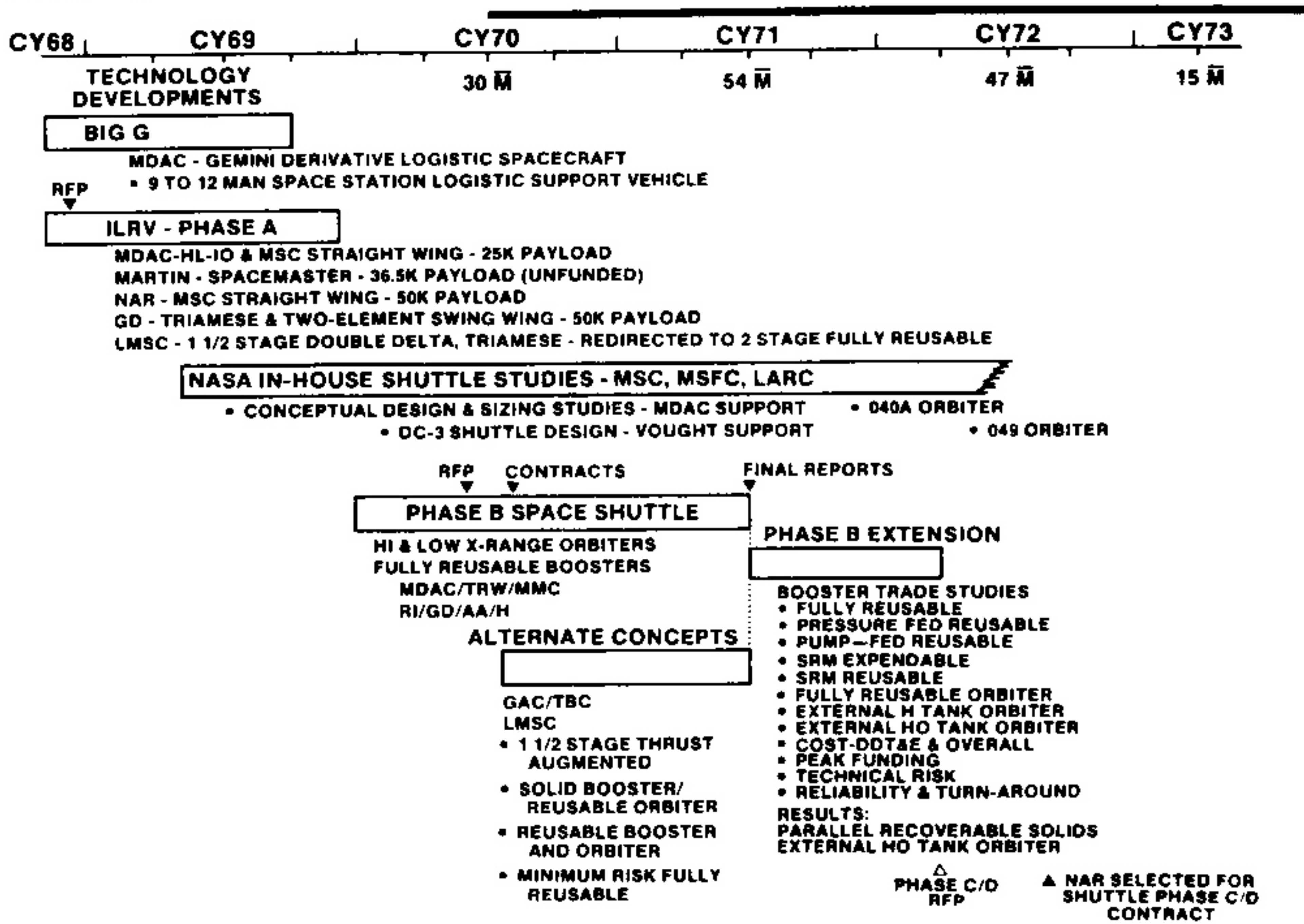
Shuttle Definition Activity

Figure 3



Shuttle Definition Activity
External Tank

Figure 4

PRO

- CONCERN AS TO VERIFICATION OF INTERNAL TANKS FLIGHT TO FLIGHT: INSULATION INTEGRITY, LEAKAGE
- CONCERN AS TO INERTING OF INTERNAL H_2 TANKS FOR ENTRY
- CONCERN AS TO DELTA PRESSURE ON ENTRY
- OVERALL REDUCTION IN ORBITER SIZE AND EXPECTATION OF LOWER DEVELOPMENT COST/RISK
- COMBINED LH_2 — LO_2 TANK REDUCED c.g., ASCENT EXCURSIONS
- TANK STRUCTURE RELATIVELY SIMPLE AND EFFICIENT
- TANK 'STRETCH' OPTION TO OFFSET INERT WEIGHT GROWTH OR LOW THRUST PERFORMANCE

CON

- EXPENDED UNIT EACH FLIGHT ADDED TO OPERATIONS COST
- ENVIRONMENTAL CONSTRAINTS — CONCERNS RELATIVE TO DISPOSITION

Shuttle Definition Activity

- **TWO STAGE FULLY REUSEABLE**
  - **COMPLEX MISSION PROFILE**
    - BOOSTER LARGE ROCKET SYSTEM
      LARGE AIRCRAFT SYSTEM
    - ORBITER SMALLER VERSION OF SAME BASIC SYSTEMS
  - **COMPLEXITY**
    - HIGH COST
    - MULTIPLE CONCURRENT DEVELOPMENTS
    - NUMEROUS TECHNOLOGY RISKS
- **LESS COMPLEX EXTERNAL TANK ORBITER**
  - **SERIES BURN**
    - PUMP FED BOOSTER
    - PRESSURE FED BOOSTER
    - SOLID ROCKET MOTOR BOOSTER
  - **PARALLEL BURN**
    - PUMP FED AUGMENTATION
    - PRESSURE FED AUGMENTATION
    - SOLID ROCKET MOTOR AUGMENTATION

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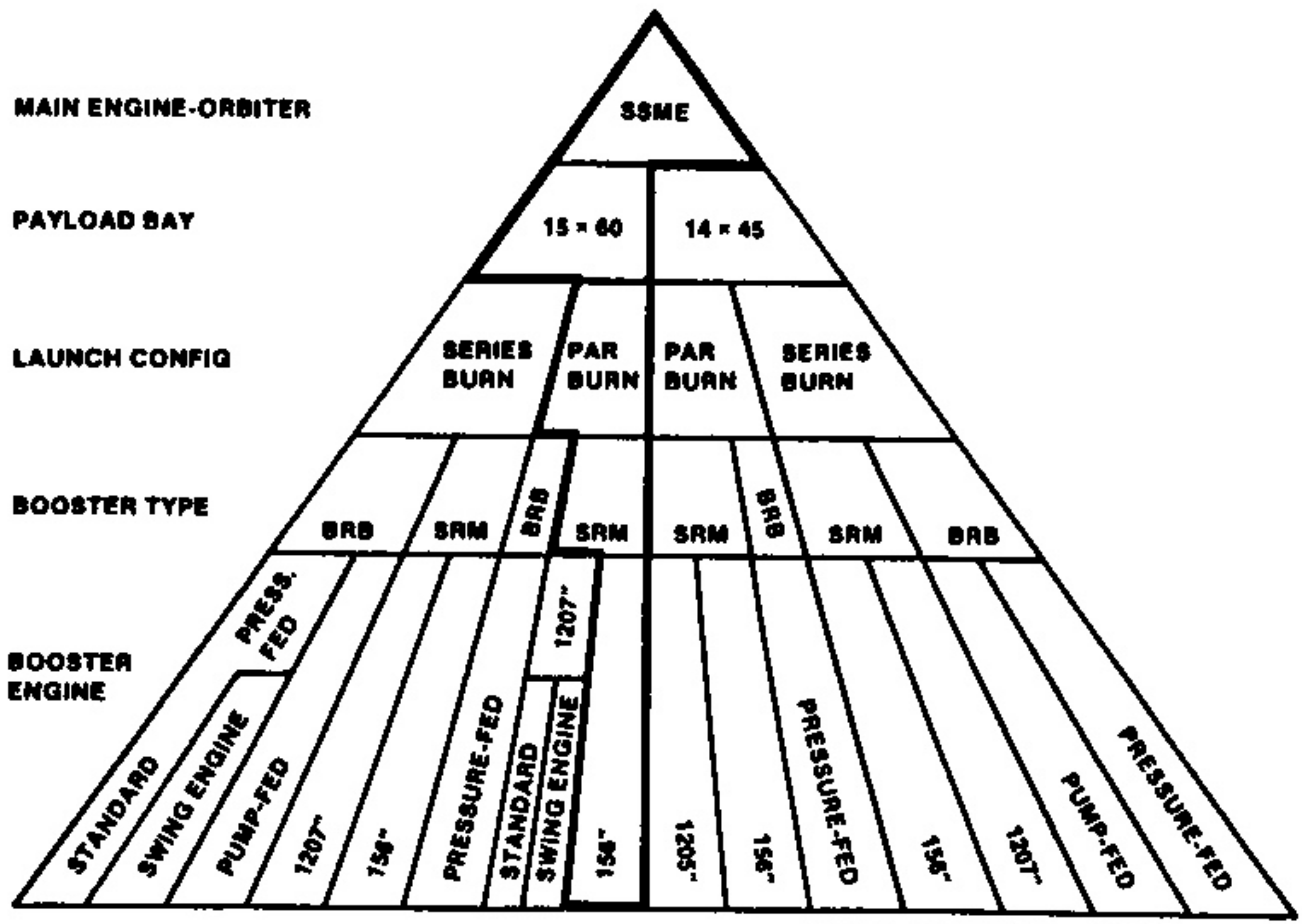
Program Options

Figure 6



SSME = SPACE SHUTTLE MAIN ENGINE
BRB = BALLISTIC ROCKET BOOSTER
SRM = SOLID ROCKET MOTOR
1205" = 120 INCH 5 SEGMENT SRM ~ TITAN
1207" = 120 INCH 7 SEGMENT SRM
156" = USAF DEVELOPED LARGE SRM

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Shuttle Definition Activity

Figure 7

- ENGINE SELECTION
  - F-1 — KEROSINE/LOX — APOLLO DERIVATIVE
  - J-2S — CRYOGENIC LOX/H_2 — APOLLO DERIVATIVE
  - SSME — CRYOGENIC LOX/H_2 — NEW ENGINE DEVELOPMENT
- HIGH IMPULSE, HIGH THRUST LEVEL REDUCED OVERALL SYSTEM SIZE AND COMPLEXITY
  - REDUCED NUMBER OF ENGINES
  - REDUCED GROSS LIFT-OFF PROPELLANT
  - NEW DESIGN MADE REUSEABILITY EASIER TO IMPLEMENT
  - THROTTLING NOT AVAILABLE AND DESIRED
  - DIGITAL CONTROLLER — CLOSED LOOP FOR DEVELOPMENT AND PRECISION CONTROL
- THRUST LEVEL — 470 VS 350 IS A CHOICE OF THREE VS FOUR ENGINES FOR THE ORBITER

Shuttle Definition Activity

Figure 8

PAYLOAD BAY SIZING

15 × 60 — 14 × 45

- PAYLOAD WEIGHT ACCOMMODATION MORE SIGNIFICANT THAN VOLUME ACCOMMODATION
- SHORTER PAYLOAD BAYS MAKE ORBITER BALANCE DIFFICULT (SMALLER REDUCED THRUST ENGINE OR LONGER PAYLOAD BAY)
- REDUCTION IN PAYLOAD BAY LENGTH HAD SMALL EFFECT ON INERT OR GROSS WEIGHT
- LARGER VOLUMES ACCOMMODATE MULTIPLE PAYLOAD AGGREGATION MORE EFFICTIVELY

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SHUTTLE DEFINITION ACTIVITY

BALLISTIC RECOVERY BOOSTERS

- SERIES BURN
  - LARGE BOOSTER — RECOVERY IS DIFFICULT
  - MULTIPLE ENGINES AND COMPLEXITY, RELIABILITY ISSUES
  - BOOSTER-ORBITER SEPARATION SIMPLE
  - SERIES STAGING EFFICIENCY
  - ORBITER ENGINE IGNITION AT STAGING
- PARALLEL BURN
  - ALL ENGINES RUNNING AT LIFT-OFF
  - EXPLOITS SSME PERFORMANCE
    - LIQUID (PUMP OR PRESSURE FED)
      - SMALLER BOOSTERS — EASIER RECOVERY
      - LOWER GROSS LIFT-OFF WEIGHT
      - BOOSTER SEPARATION COMPLEXITY
      - REFURBISHMENT COMPLEXITY
    - SOLID ROCKET MOTORS
      - SMALLEST BOOSTER — EASIEST RECOVERY
      - LOWEST GROSS WEIGHT
      - BOOSTER SEPARATION COMPLEX
      - SIMPLEST SYSTEM TO REFURBISH
      - HIGH RELIABILITY
      - ENVIRONMENTAL CONCERNS

Figure 10

NASA Lyndon B. Johnson Space Center

Engineering Directorate

SHUTTLE SYSTEMS DESIGN EVOLUTION 1972 - 1973	ORBITER SYSTEMS INTEGRATION OFFICE	
	PHILIP M. DEANS	9-18-84

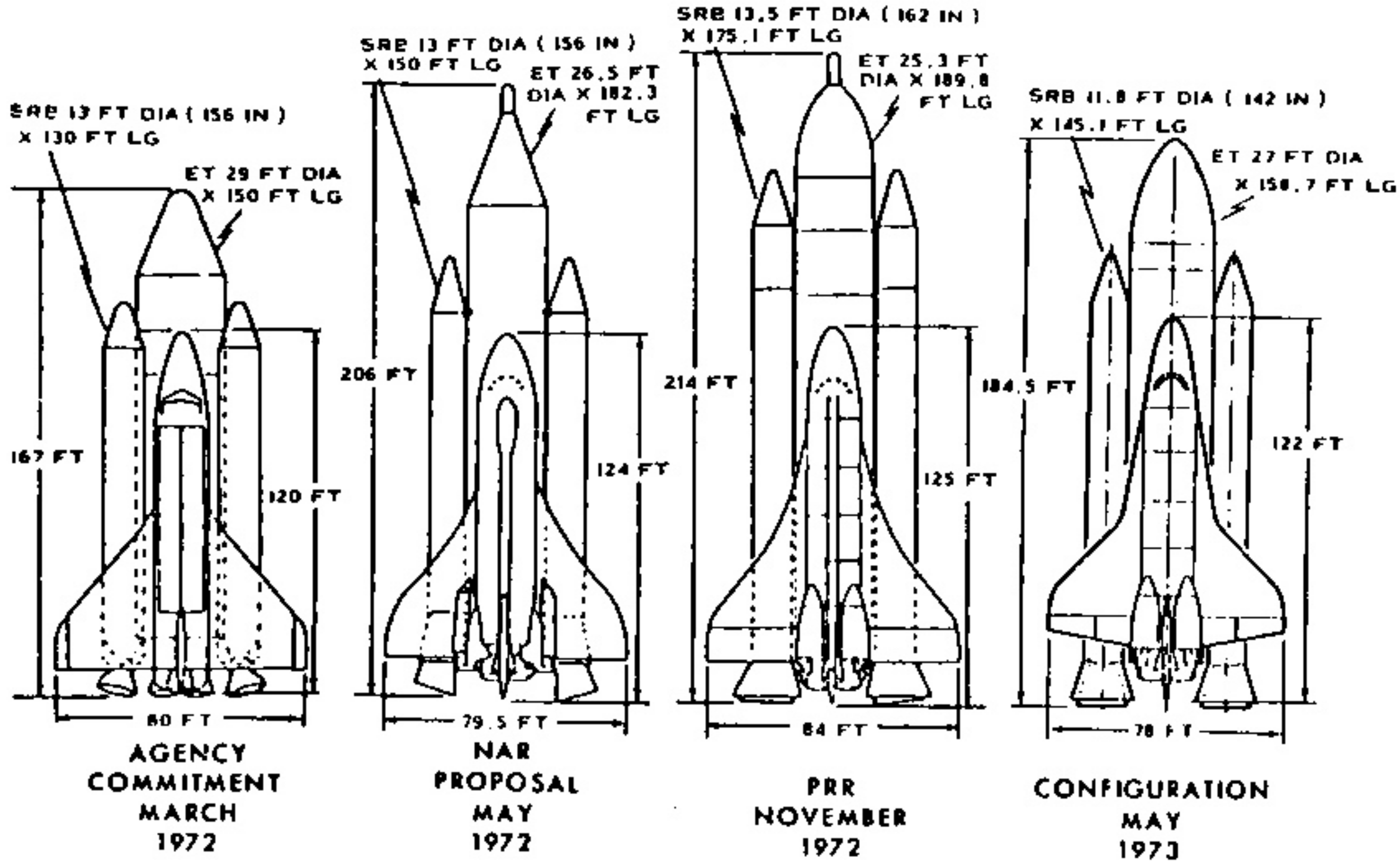
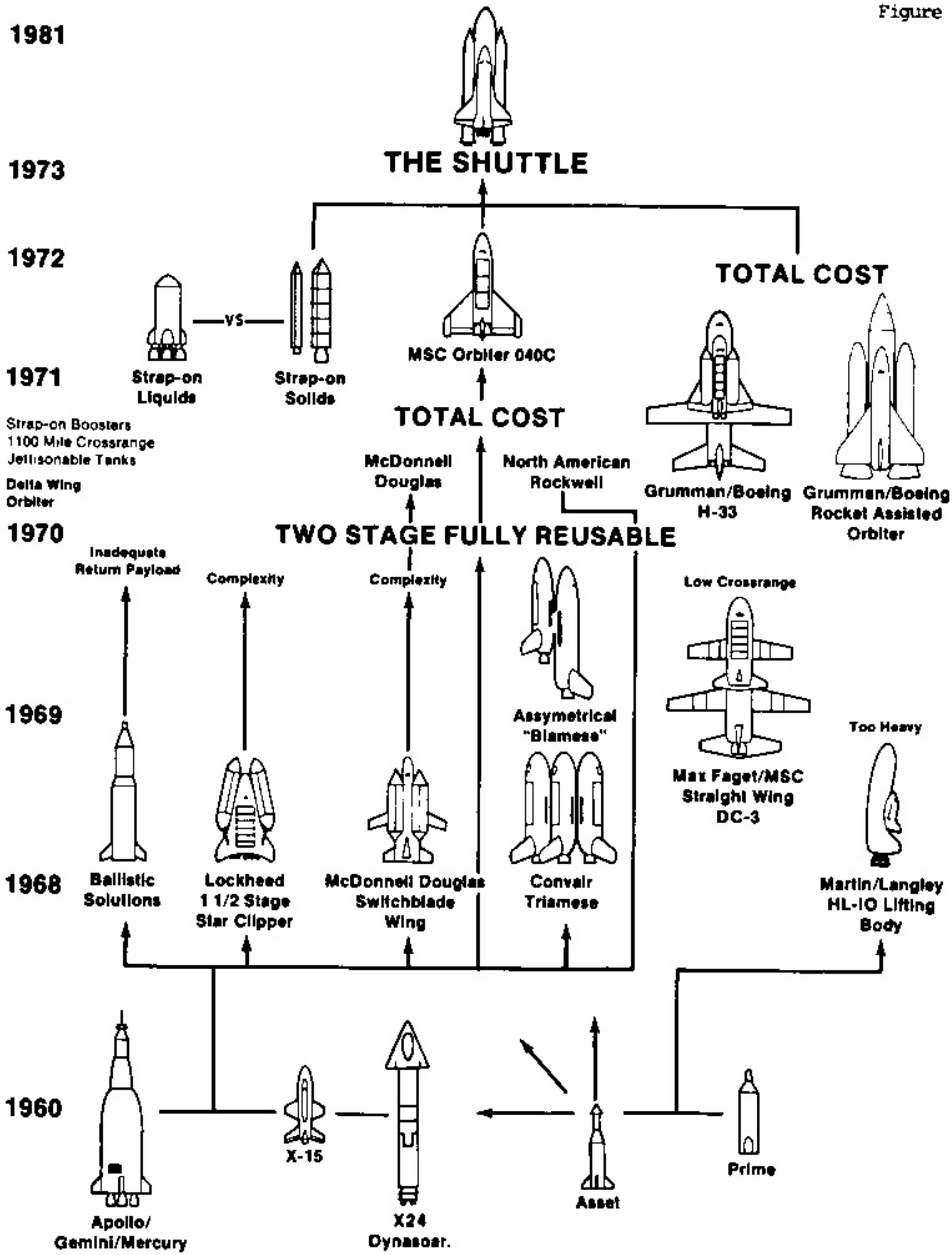


Figure 11



1981
THE SHUTTLE
1973
1972
TOTAL COST
VS
1971
Strap-on Liquids
Strap-on Solids
MSC Orbiter 040C
TOTAL COST
Strap-on Boosters
1100 Mile Crossrange
Jettisonable Tanks
Delta Wing Orbiter
McDonnell Douglas
North American Rockwell
Grumman/Boeing H-33
Grumman/Boeing Rocket Assisted Orbiter
1970
TWO STAGE FULLY REUSABLE
Inadequate Return Payload
Complexity
Complexity
Low Crossrange
1969
Assymetrical "Siamese"
Too Heavy
Max Faget/MSC Straight Wing DC-3
1968
Ballistic Solutions
Lockheed 1 1/2 Stage Star Clipper
McDonnell Douglas Switchblade Wing
Convair Triamese
Martin/Langley HL-IO Lifting Body
1960
X-15
Prime
Asset
Apollo/ Gemini/Mercury
X24 Dynasoar.

Figure 12

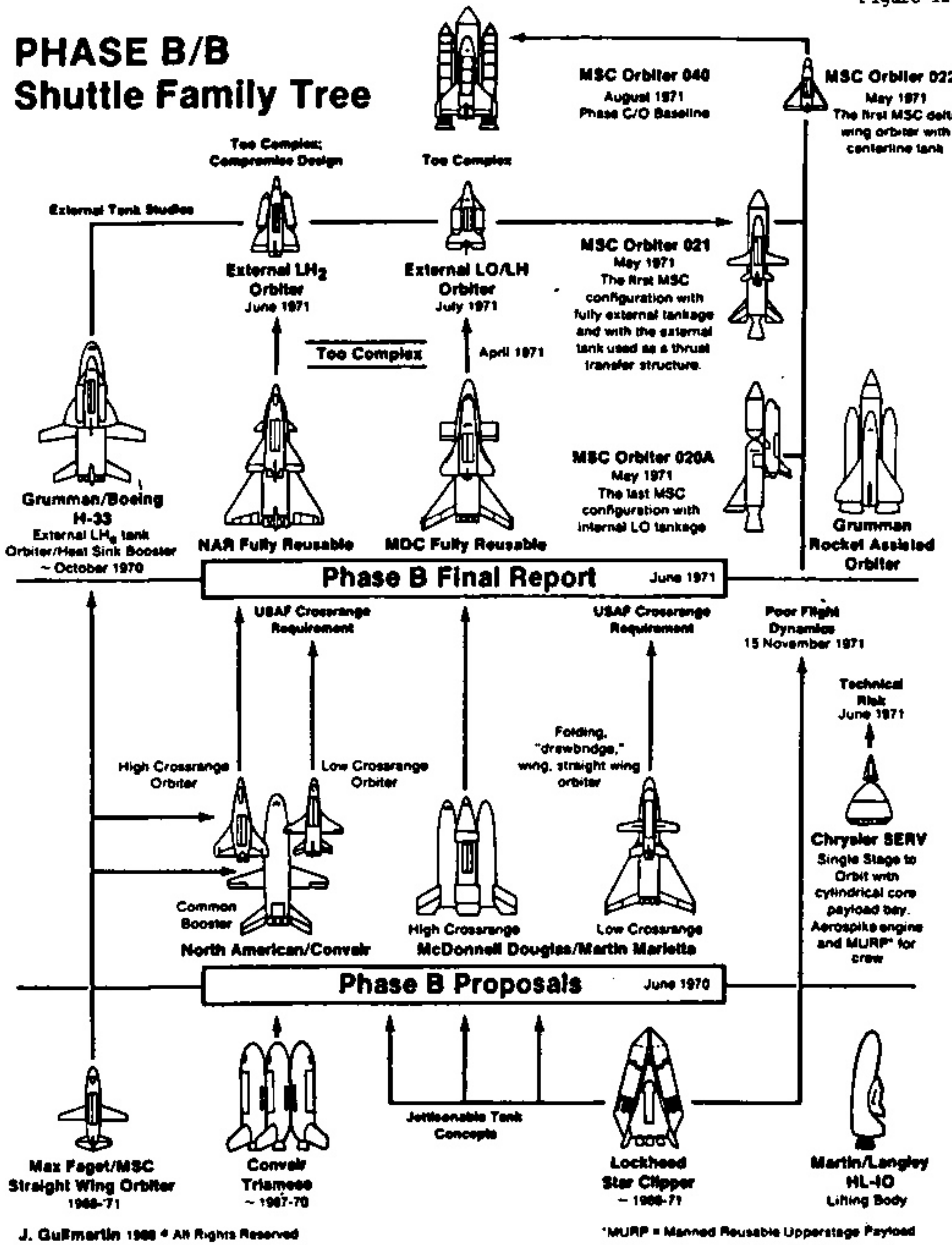
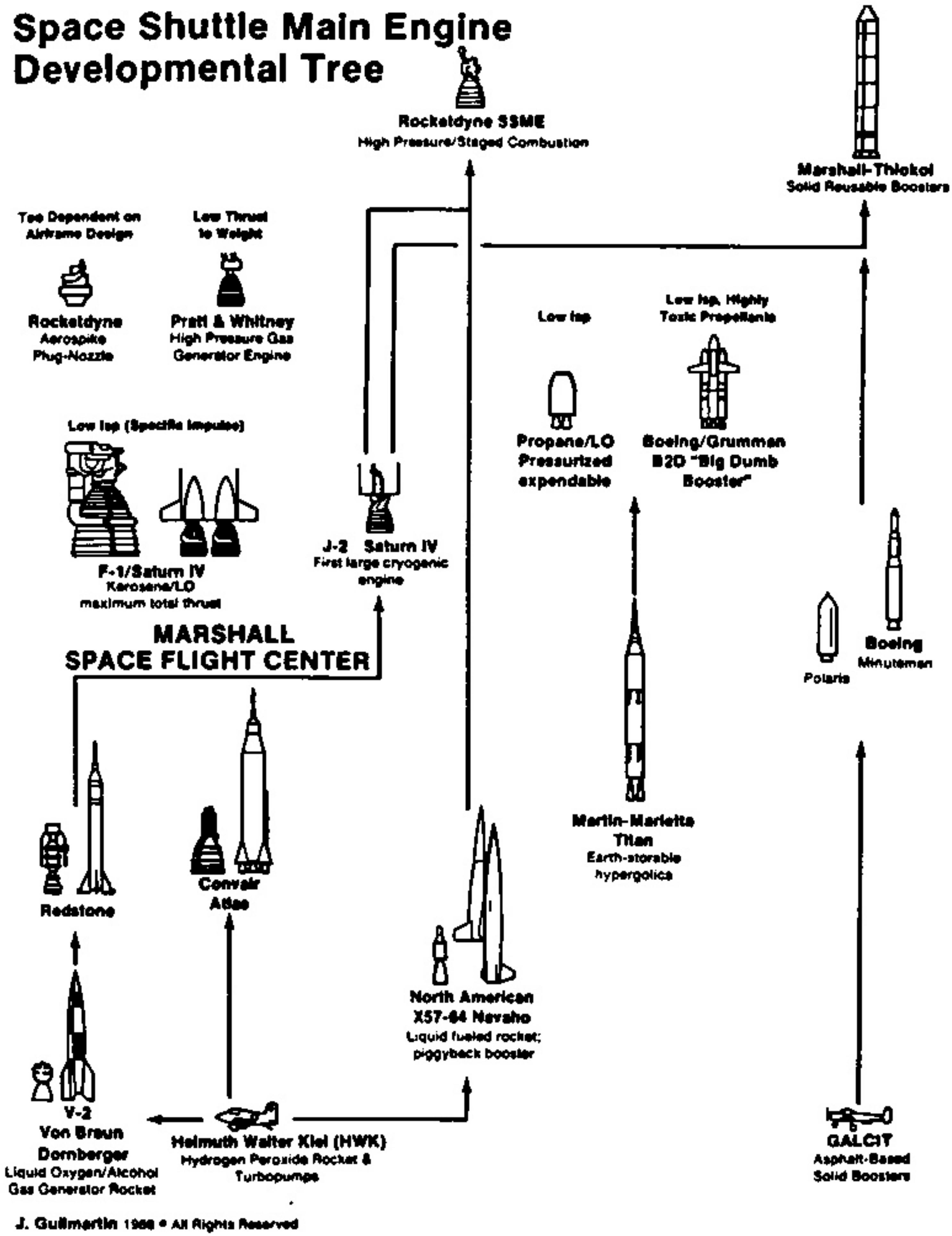

PHASE B/B
Shuttle Family Tree
MSC Orbiter 040
August 1971
Phase C/D Baseline
MSC Orbiter 022B
May 1971
The first MSC delta wing orbiter with centerline tank
Too Complex;
Compromise Design
Too Complex
External Tank Studies
External LH$_2$ Orbiter
June 1971
External LO/LH Orbiter
July 1971
MSC Orbiter 021
May 1971
The first MSC configuration with fully external tankage and with the external tank used as a thrust transfer structure.
Too Complex
April 1971
Grumman/Boeing
H-33
External LH$_2$ tank
Orbiter/Heat Sink Booster
~ October 1970
NAR Fully Reusable
MDC Fully Reusable
MSC Orbiter 020A
May 1971
The last MSC configuration with internal LO tankage
Grumman
Rocket Assisted
Orbiter
Phase B Final Report
June 1971
USAF Crossrange
Requirement
USAF Crossrange
Requirement
Poor Flight
Dynamics
15 November 1971
Technical
Risk
June 1971
High Crossrange
Orbiter
Low Crossrange
Orbiter
Folding,
"drawbridge,"
wing, straight wing
orbiter
Common
Booster
North American/Convair
High Crossrange
Low Crossrange
McDonnell Douglas/Martin Marietta
Chrysler SERV
Single Stage to Orbit with cylindrical core payload bay.
Aerospike engine and MURP* for crew
Phase B Proposals
June 1970
Jettisonable Tank
Concepts
Max Faget/MSC
Straight Wing Orbiter
1969-71
Convair
Triamese
~ 1967-70
Lockheed
Star Clipper
~ 1966-71
Martin/Langley
HL-10
Lifting Body
J. Guilmartin 1988 © All Rights Reserved
*MURP = Manned Reusable Upperstage Payload

Figure 13


Space Shuttle Main Engine
Developmental Tree
Rockeldyne SSME
High Pressure/Staged Combustion
Marshall-Thiokol
Solid Reusable Boosters
Too Dependent on
Airframe Design
Low Thrust
to Weight
Rocketdyne
Aerospike
Plug-Nozzle
Pratt & Whitney
High Pressure Gas
Generator Engine
Low Isp
Low Isp, Highly
Toxic Propellants
Propane/LO
Pressurized
expendable
Boeing/Grumman
B2D "Big Dumb
Booster"
Low Isp (Specific Impulse)
F-1/Saturn IV
Kerosene/LO
maximum total thrust
J-2 Saturn IV
First large cryogenic
engine
MARSHALL
SPACE FLIGHT CENTER
Boeing
Minuteman
Polaris
Martin-Marietta
Titan
Earth-storable
hypergolics
Redstone
Convair
Atlas
North American
X57-64 Navaho
Liquid fueled rocket;
piggyback booster
V-2
Von Braun
Dornberger
Liquid Oxygen/Alcohol
Gas Generator Rocket
Helmuth Walter Kiel (HWK)
Hydrogen Peroxide Rocket &
Turbopumps
GALCIT
Asphalt-Based
Solid Boosters
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