Liquid Rocket Engine

WBS Item Name: ____

Engine Globals

Production Rate per Year	30	__________
Production Quantity	1	__________
QNHA (# engine/system)	1	__________
Contingency Percentage	0	__________
Program Support Percentage	0	__________
Fee Percentage	0	__________

Development

Hardware Development

Engine Design and Manufacturing Maturity

	Factor	Representative Engine	Maturity Definition
____	1.90	SSME	New design/manufacturing, state of art being advanced or multiple design or material and process paths required to reach goals.
____	1.30		New design, different from established product line. Requires in-house development of new materials & process
____	1.00	F-1, J-2	New design, different from established product line. Uses existing materials.
____	0.90	J-2S	New design, within the established product line, continuation of existing state of art.
____	0.60		Extensive modifications to an existing design.
____	0.20	RS-27, MA-5A	Simple modification to an existing design.

Engine Certification Process Improvement Factor

	Factor	Representative Engine	Maturity Definition
____	4.20	F-1, J-2	Full qualification of components and engine system, formal reliability demonstration, heavy reliance on testing to resolve failures and evaluate different design concepts, customer-originated requirement changes, engine block changes.
____	1.00		Similarity rationale, formal reliability demonstration.
____	0.50	SSME	Design verification system, recertification of reliability demonstration.
____	0.20	DS-27, MA-5A	Design verification system, recertification of previous engine, TQM.

Engine Cycle & Internal Environment Complexity

	Factor	Representative Engine	Cycle Description
____	1.20	J-2S	Staged Combustion (two 'mixed' preburners)
____	1.00		Hybrid
____	0.80	F-1, J-2, RS-27, MA-5A	Gas Generator
____	0.70		Expander
____	0.60	SSME	Tap-off

Development Engine Fab Time Span (Years) 3 ________

Test Labor

Test Labor Process Improvement Factor

	Factor	Representative Engine	Process Description
____	1.00	F-1, J-2, SSME	Business as usual
____	0.20	New Engines	Improved testing/post testing procedures and manpower utilization

Test Frequency (Number of Test per Month)	30	________
Test Reduction Factor	1	________

Design Engineering Process Improvement Factor

	Factor	Representative Engine	Process Description
____	1.00	F-1, J-2	No CAD, CFD, little design automation, mostly handbooks, templates.
____	0.44	SSME	Limited design automation, but CAD and some SFD.
____	0.30	New Engines	Significant design automation, concurrent engineering, TQM.

Tooling, GSE, & STE Cost

Tooling Cost Improvement Factor

	Factor	Tooling Description
____	1.00	Apollo era type tooling
____	0.60	Modern type tooling [Modular tooling fab. simplification (reduced parts count)]

Tooling Availability Factor

	Factor	Tooling Description
____	1.00	New eng. or complete retooling or adv. fab. for majority of engine components
____	0.75	Partial use of existing tooling
____	0.50	New tooling design for simplified engine fabrication

____ **0.25** **Significant use of existing tooling**

Summary Production Model

Cycle, Propellant, and Reusability Dependent Factor

____ **Gas generator or tap-off, Expendable, LOX/RP-1**
____ **Gas generator or tap-off, Expendable, LOX/LH2**
____ **Gas generator or tap-off, Reusable, LOX/RP-1**
____ **Gas generator or tap-off, Reusable, LOX/LH2**
____ **Staged combustion/dual preburner, Expendable, LOX/RP-1**
____ **Staged combustion/dual preburner, Expendable, LOX/LH2**
____ **Staged combustion/dual preburner, Reusable, LOX/RP-1**
____ **Staged combustion/dual preburner, Reusable, LOX/LH2**
____ **Staged combustion/single preburner, Expendable, LOX/RP-1**
____ **Staged combustion/single preburner, Expendable, LOX/LH2**
____ **Staged combustion/single preburner, Reusable, LOX/RP-1**
____ **Staged combustion/single preburner, Reusable, LOX/LH2**
____ **Hybrid, Expendable, LOX/LH2**
____ **Hybrid, Reusable, LOX/LH2**

Producibility Improvement Factor

____ **No producibility improvement, i.e. historical manufacturing environment.**
____ **Design simplification only, no manufacturing improvement.**
____ **Design simplification & mfg. improvement for derivative, expendendable engines.**
____ **Clean sheet design of new, low perf., expendable eng. w/high producibility.**

Manufacturing Automation Factor

____ **Conventional manufacturing environment**
____ **Fully Computer Integrated Mfg. (CIM) for rate > 50/yr; 0% govt. investment.**
____ **Fully Computer Integrated Mfg. (CIM) for rate > 50/yr; 50% govt. investment.**
____ **Fully Computer Integrated Mfg. (CIM) for rate > 50/yr; 100% govt. investment.**

Vacuum Thrust (kbs) _________ **(The suggested range is 20 Klbs to 2000 Klbs.)**

Chamber Pressure (psi) _________ **(The suggested range is 500 psi to 4000 psi.)**

Detailed Production Model

Ducts

____ Complex Oxygen/Hydrogen Ducts CER
____ Complex Oxygen/RP-1 Ducts CER
____ Simple Oxygen/RP-1 Ducts CER
____ Known Cost CER

Weight __________ **lbs** _________ **kgs**

Quantity per Engine 1 _________

Known TFU Cost in 99$ M _________

NWODB Adjustment Factors

Manufacturing Support Labor

____ Historical Support Factor
____ Manufacturing Support Improvements
____ Design and Fabrication Improvements
____ Factory of the Future Environment

Degree of Outsourcing

____ Moderate Level of Outsourcing
____ Retain Strategic Work In-House
____ Most Work Outsourced
____ Work Done Mostly In-House

Detailed Production Model

Gimbals

____ Gimbal CER
____ Known Cost CER

Weight __________ **lbs** _________ **kgs**

Quantity per Engine 1 _________

Known TFU Cost in 99$ M _________

NWODB Adjustment Factors

Manufacturing Support Labor

____ Historical Support Factor
____ Manufacturing Support Improvements
____ Design and Fabrication Improvements
____ Factory of the Future Environment

Degree of Outsourcing

____ Moderate Level of Outsourcing
____ Retain Strategic Work In-House
____ Most Work Outsourced
____ Work Done Mostly In-House

Detailed Production Model

Main Injector Assemblies

____ **Complex Injector CER**
____ **Doublet Injector CER**
____ **Known Cost CER**

Weight __________ **lbs** _________ **kgs**

Quantity per Engine 1 _________

Known TFU Cost in 99$ M _________

NWODB Adjustment Factors

Manufacturing Support Labor

____ **Historical Support Factor**
____ **Manufacturing Support Improvements**
____ **Design and Fabrication Improvements**
____ **Factory of the Future Environment**

Degree of Outsourcing

____ **Moderate Level of Outsourcing**
____ **Retain Strategic Work In-House**
____ **Most Work Outsourced**
____ **Work Done Mostly In-House**

Detailed Production Model

Main Valves

____ Oxygen/Hydrogen Valves CER
____ Oxygen/RP-1 Valves CER
____ Known Cost CER

Weight __________ **lbs** _________ **kgs**

Quantity per Engine 1 _________

Known TFU Cost in 99$ M _________

NWODB Adjustment Factors

Manufacturing Support Labor

____ Historical Support Factor
____ Manufacturing Support Improvements
____ Design and Fabrication Improvements
____ Factory of the Future Environment

Degree of Outsourcing

____ Moderate Level of Outsourcing
____ Retain Strategic Work In-House
____ Most Work Outsourced
____ Work Done Mostly In-House

Detailed Production Model

Thrust Chamber Assemblies

____ Channel Construction CER
____ Tubular Construction CER
____ Known Cost CER

Weight __________ **lbs** _________ **kgs**

Quantity per Engine 1 _________

Known TFU Cost in 99$ M _________

NWODB Adjustment Factors

Manufacturing Support Labor

____ Historical Support Factor
____ Manufacturing Support Improvements
____ Design and Fabrication Improvements
____ Factory of the Future Environment

Degree of Outsourcing

____ Moderate Level of Outsourcing
____ Retain Strategic Work In-House
____ Most Work Outsourced
____ Work Done Mostly In-House

Detailed Production Model

Turbopumps

____ **Torque Driven CER**
____ **Weight Driven CER**
____ **Known Cost CER**

Torgue (ft-lbf) _________

Weight __________ **lbs** _________ **kgs**

Quantity Per Engine 1 _________

Known TFU Cost in 99$ M _________

Number of Key Parts

Impellars (Main & Kick)	1	__________
Inducers	1	__________
Crossovers (Between Stages)	0	__________
Volutes (Main & Kick, Double Entry Counts as 2)	1	__________
Turbine Rotors	2	__________
Turbine Stators (Turbine Nozzle)	2	__________
Purge Seals	1	__________
Turbine Inlet Manifold	0	__________
Turbine Exit Manifold	0	__________
Shafts (One per T/P to Account for Bearing and Seal Set)	1	__________
Enter –1 if Turbine and Pump Fluids are the Same, 0 if not	0	__________
Total	9	__________

NWODB Adjustment Factors

Manufacturing Support Labor

____ **Historical Support Factor**
____ **Manufacturing Support Improvements**
____ **Design and Fabrication Improvements**
____ **Factory of the Future Environment**

Degree of Outsourcing

____ **Moderate Level of Outsourcing**
____ **Retain Strategic Work In-House**
____ **Most Work Outsourced**

____ **Work Done Mostly In-House**

Detailed Production Model

Preburner/Gas Generator Injector Assemblies

____ Coaxial Injector CER
____ Doublet Injector CER
____ Known Cost CER

Weight __________ **lbs** _________ **kgs**

Quantity per Engine 1 _________

Known TFU Cost in 99$ M _________

NWODB Adjustment Factors

Manufacturing Support Labor

____ Historical Support Factor
____ Manufacturing Support Improvements
____ Design and Fabrication Improvements
____ Factory of the Future Environment

Degree of Outsourcing

____ Moderate Level of Outsourcing
____ Retain Strategic Work In-House
____ Most Work Outsourced
____ Work Done Mostly In-House