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Space Shuttle Processing Simulation Model

Macro Level Simulation Model Of Space Shuttle Processing

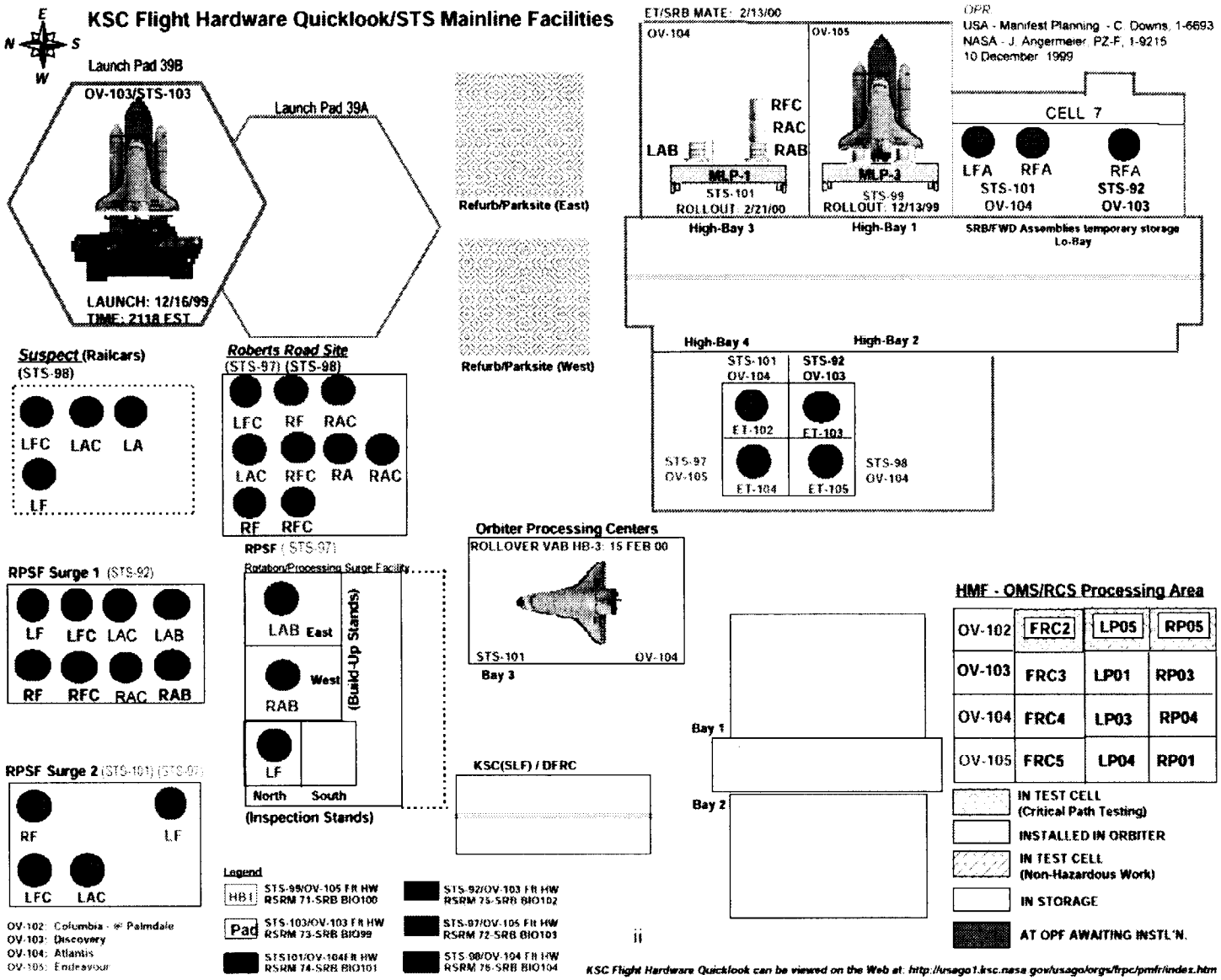
Developed under a NASA Space Act Agreement
between the Kennedy Space Center and the University of Central Florida

"ST Day 2000: Reducing Risk for the Next Generations"

- **The simulation model encompasses the existing space shuttle ground processing Facilities, Ground-Support Equipment (GSE) infrastructure and Flight-Hardware elements to the level of detail that NASA retains management responsibility for; such as...**

Flight Hardware	Facilities	GSE
Orbiters	OPF	Orbiter Transporter
SSMEs	Engine Shop	Engine Hyster
External Tanks	VAB	ET Transporter
SRM/SRB	MLPs	Crawler/Transporter

- **The simulation model logic is consistent with current Space Shuttle program ground rules and constraints such as...**
  - After 8 flights, the shuttle orbiter undergoes depot level maintenance (OMDP/OMMP) in California.
  - only one shuttle on orbit at any given time.



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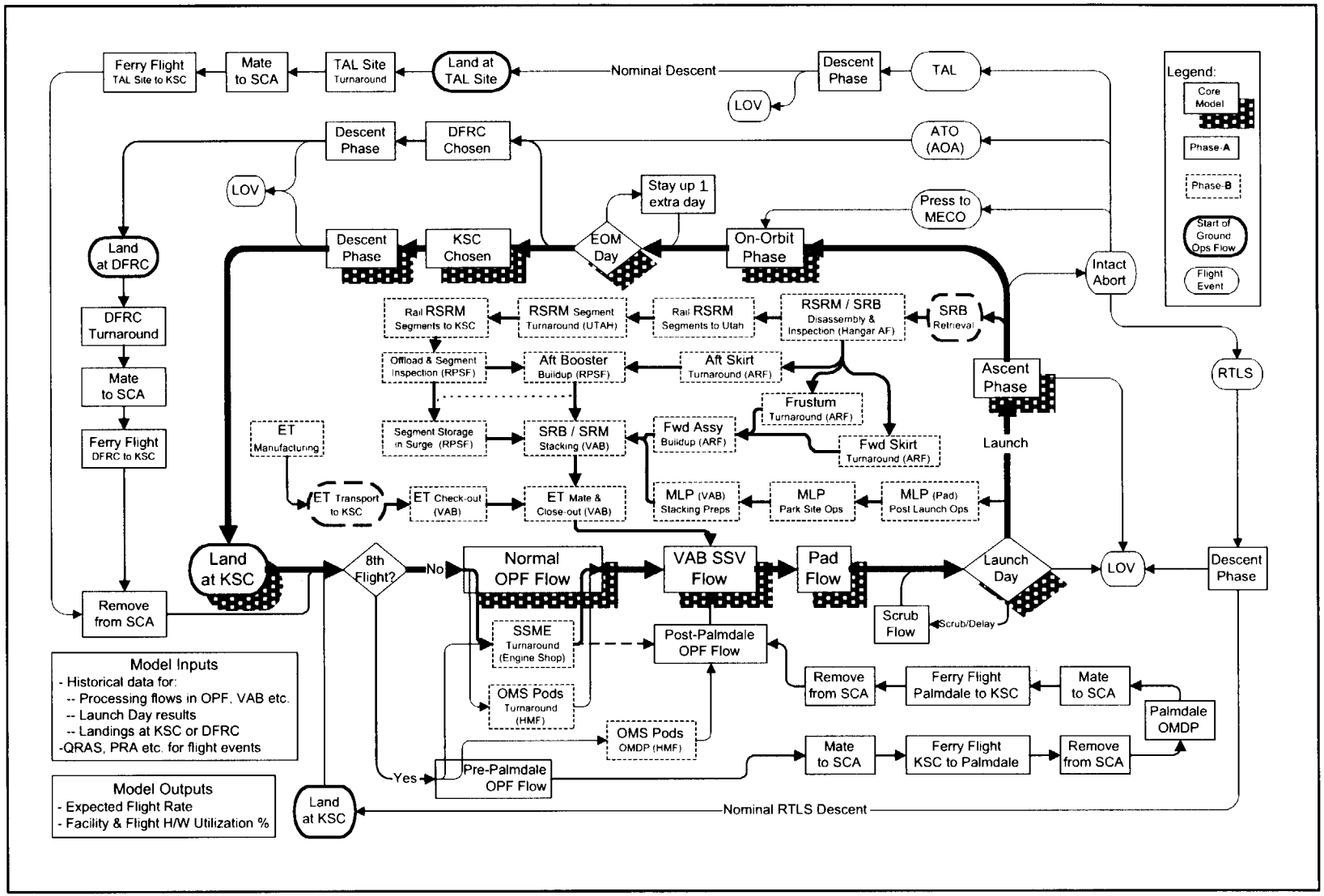

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Space Shuttle Processing Simulation Model

Flow Diagram

Utilized commercial off-the-shelf Software

Rockwell Software Arena* **Systems Modeling*	Simulation Software
Microsoft Project	Project Schedule
Microsoft Excel	Data Files
Microsoft PowerPoint	Knowledge Files & Presentations
Microsoft Visio	Flow Diagrams
Averill M. Law & *Associates, Inc. ExpertFit*	Distribution Fitting

Process Title	Process Location	File
"Normal" OPF Flow	OPF	OPF Flow.ppt OPF UCF TA Days.xls
VAB SSV Flow	VAB Integration Cell	VAB SSV Flow.ppt VAB SSV TA Days.xls
Pad Flow	Launch Pad	Pad Flow.ppt Pad Flow UCF.xls
Launch Day	Launch Pad	Launch Day.ppt Launch Data.xls
Scrub Flow	Launch Pad	Scrub Flow.ppt Launch Data.xls
Ascent Phase / Intact Abort Scenario's		Ascent.ppt SAIC Midterm Abort.ppt Risk PRA.xls
On-Orbit Phase	LEO	On-Orbit.ppt On Orbit UCF.xls
End of Mission (EOM) Day	LEO	On-Orbit.ppt Landings.xls
Land at KSC	SLF	KSC Landing.ppt Landings.xls
Land at DFRC	Edwards Air Force Base, CA	DFRC Landing.ppt Landings.xls
Land at TAL Site	Spain or Africa	TAL Landing.ppt
Mobile Launcher Platform (MLP) Life	Launch Pad, MLP Park Site, VAB	MLP UCF Phase- MLP TA Days.xls

Process Title	Process Location	File
SRB Retrieval	Atlantic Ocean	SRB Retrieval.ppt
SRM / SRB Disassembly & Inspection	Hangar AF	SRB Safng Disassy.ppt
RSRM Off-Site Turnaround Cycle	Utah	RSRM.ppt
	Rail Roads	RSRM Transit Time.xls
Rail RSRM Segments to Utah	Rail Roads	RSRM KSC Time.xls
SRB Subassembly Turnaround Cycle	ARF	SRB ARF.ppt SRB ARF Data.xls
RPSF Operations	RPSF	RPSF.ppt SRB Aft Booster Bld Up.xls
SRB/SRM Stacking	VAB Integration Cell	SRB Stacking.ppt
ET Manufacturing	Michoud, LA	ET Manufacturing.ppt
ET Transport to KSC	LA to FL	ET Manufacturing.ppt
ET Checkout	Checkout Cell	ET Check Mate.ppt ET Ck-Out TA Days.xls
ET Mate & Closeouts	VAB Integration Cell	ET Check Mate.ppt ET TA Days.xls
SSME Turnaround	OPF, VAB, Pad, Engine Shop	SSME UCF Phase B.ppt SSME Data.xls
OMS Pods & FRCS Contingency Turnaround	HMF	OMS Pods & FRCS.ppt HMF History.xls
OMS Pods & FRCS OMDP Flows	HMF	OMS Pods & FRCS OMDP.ppt HMF History.xls
Orbiter OMDP	OPF, Palmdale	Orbiter OMDP.ppt Omdpflows UCFrev A.xls

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Space Shuttle Processing Simulation Model Knowledge Acquisition

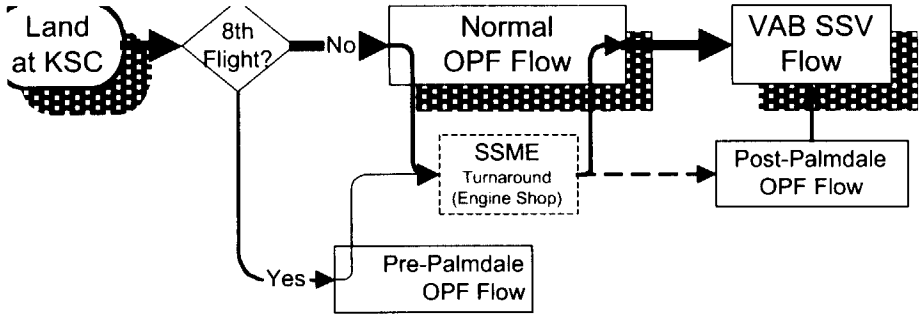


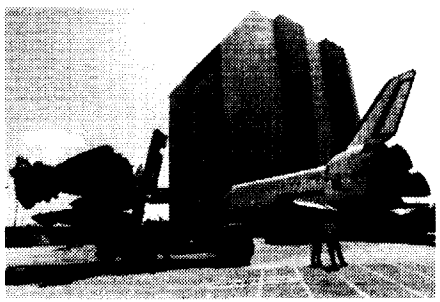
Diagram at left is the SSME related portions of the model.

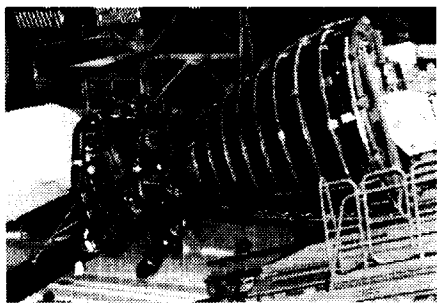
Of interest from a modeling standpoint is:

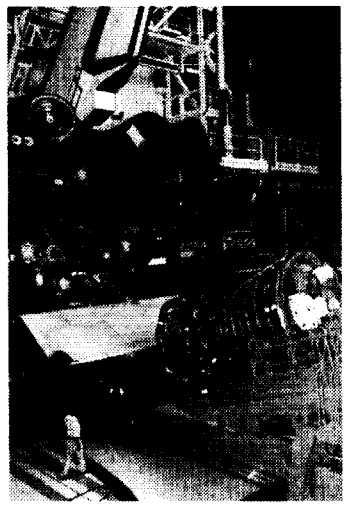
- How long from OPF roll-in to SSME removal.
- Travel time between OPF and Engine Shop.
- Duration of Engine Shop activity.
- Minimum time between engines-out and engines-in.
- Duration between SSME installation and OPF roll-out.

Initial modeling assumptions and subsequent changes :

- The engine set (3 engines) stays together. (Changed to allow engines to be separated in the engine shop
- There are 13 engines and thus four sets of engines plus one ready spare engine. (Changed to 21 engines or 7 sets to more closely reflect 1992-1997 time-frame)
- The engine shop can process one set of engines at a time. (Changed to any number of engines at a time)
- Any engine set can go in any orbiter on a first need, first served basis.
- Engine removal during a Pre-Palmdale OPF Flow is modeled the same as Normal OPF Flow.







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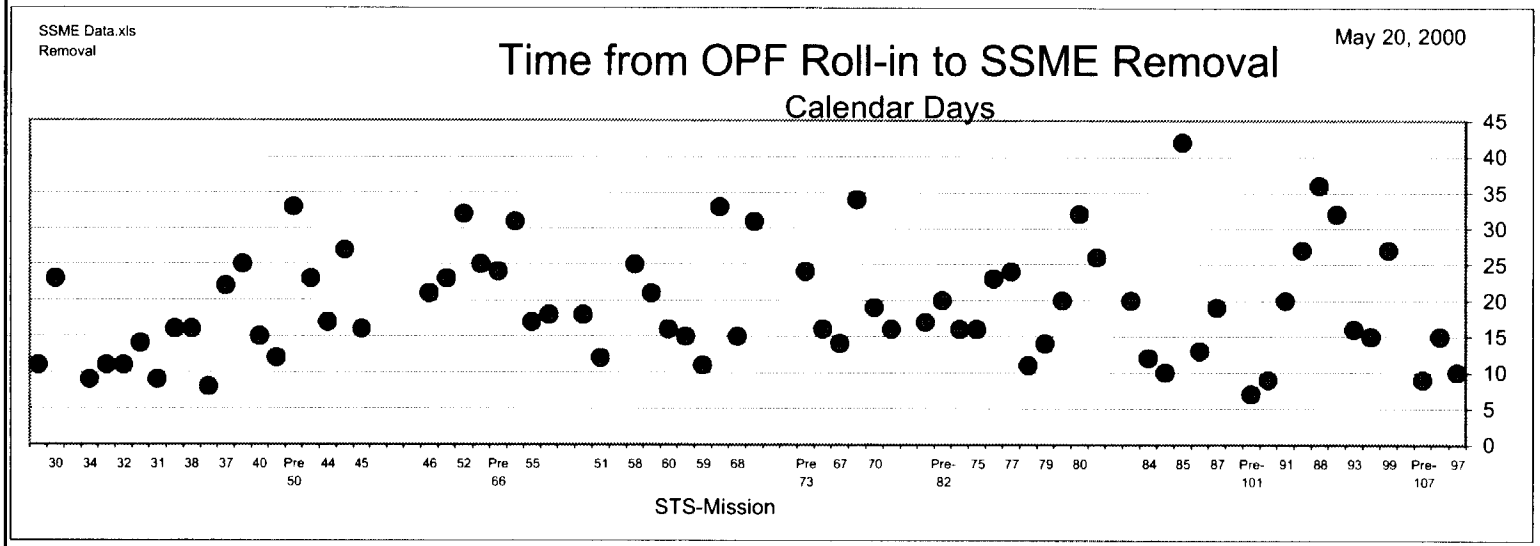
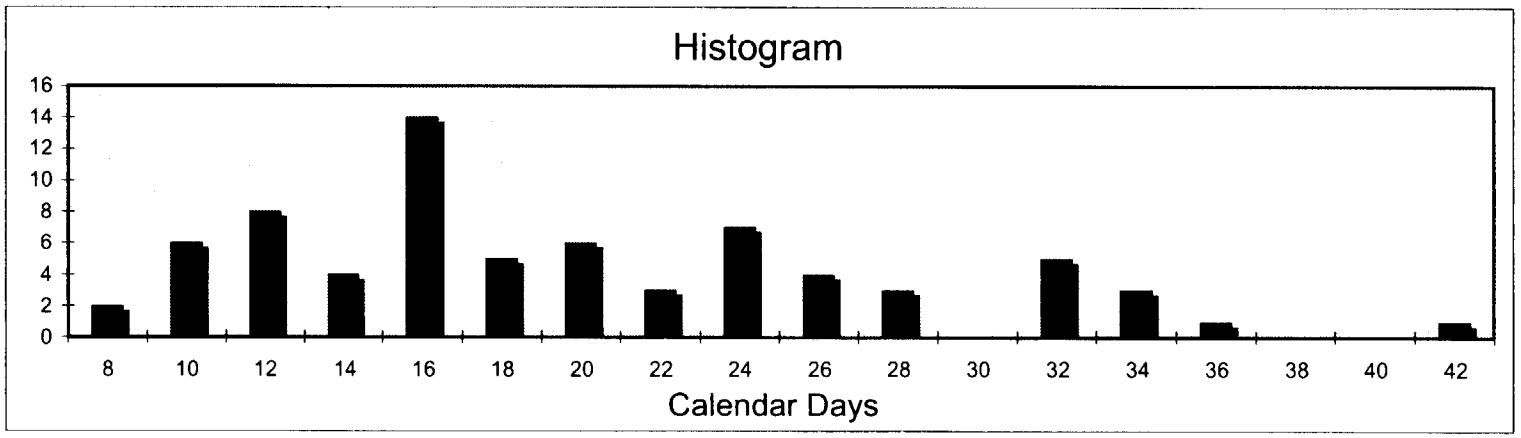
Space Shuttle Processing Simulation Model Knowledge Acquisition Excerpts from Introductory Briefings

Example of historical data

Mean	19.26
Median	17.00
Mode	16
Min	7
Max	42
Std Dev	7.795
Count	72

Bin	*Freq*
8	2
10	6
12	8
14	4
16	14
18	5
20	6
22	3
24	7
26	4
28	3
30	0
32	5
34	3
36	1
38	0
40	0
42	1





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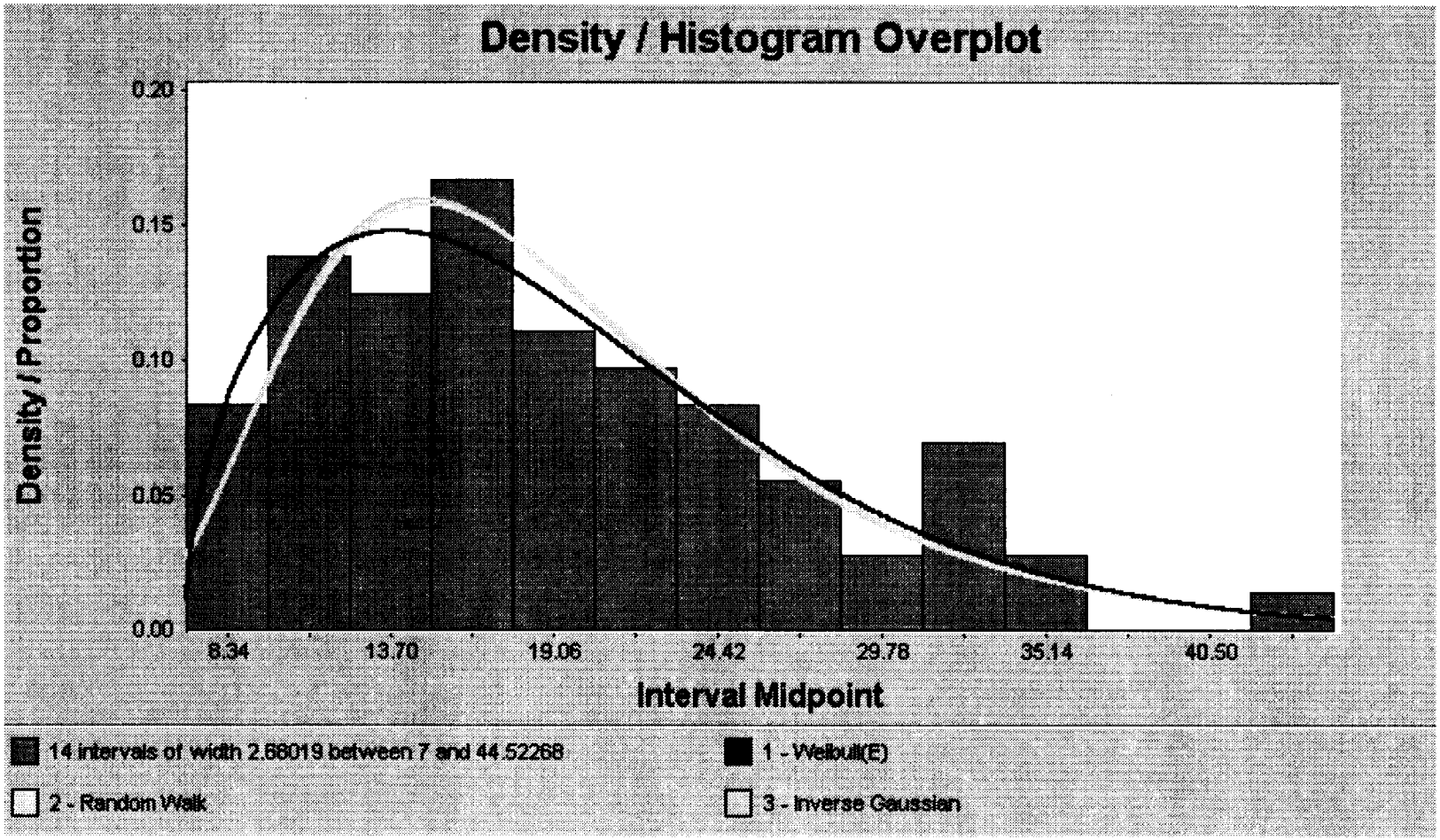
Space Shuttle Processing Simulation Model Knowledge Acquisition

Example of Probability Distribution Selection using ExpertFit: OPF Roll-in to SSME Removal



A functional probabilistic based simulation of space shuttle operations now exists and can be used for several applications:

- **Analysis of present Space Shuttle System**
  - Identify Facility & Flight Hardware Utilization percentages
  - Identify potential bottlenecks
- **Flight Rate Experiments**
  - Manipulate process-duration probability distributions to achieve 10 (or more) flights per year and analyze model outputs.
- **What-if questions can be analyzed such as:**
  - What is the expected impact on flight rate given the loss of a launch pad?
  - What is the expected impact on flight rate given the loss of one VAB Integration Cell?
- **The current model offers an architecture that allows lower level detail to be modeled for system specific operational processes or events.**

- **The existing model can serve as a First Generation RLV baseline for comparison**
  - Aid in understanding and serve as a point of departure for new reusable Space Launch Initiatives
- **New RLV specific models can be used to increase insight into reusable launch vehicle turnaround, operational processes and business case closure risk.**
  - Demonstrate Flight Rate dependence on such factors as the RLV architecture, probabilistic processing times, launch scrubs, and ascent outcomes.
- **Provide the government with a tool for analyzing and comparing competing architectures**
  - Requires that each architecture be modeled using similar methodology.