73rd MORSS CD Cover Page

712CD

UNCLASSIFIED DISCLOSURE FORM CD Presentation

For office use only 41205

21-23 June 2005, at US Military Academy, West Point, NY

Please complete this form 712CD as your cover page to your electronic briefing submission to the MORSS CD. Do not fax to the MORS office.

Author Request (To be completed by applicant) - The following author(s) request authority to disclose the following presentation in the MORSS Final Report, for inclusion on the MORSS CD and/or posting on the MORS web site.

Name of Principal Author and all other author(s):

Thomas H. Jacobs, Simulation Engineer, AFRL/VACD
2180 8th St. B-145 R- 42 WPAFB OH 45433 Ph: 937-904-6520 Fax: 937-255-9746 thomas.jacobs@wpafb.af.mil

Dr. George M. Huntley, ALMC Instructor
2401 Quarters Rd Fort Lee, Virginia 23801 Ph: 804-765-4265 Fax: 804-765-4648 george.huntley@us.army.mil

Elan T. Smith, Sr. Software Engineer, General Dynamics
5200 Springfield Pike, Suite 200 Dayton, Ohio 45431 Ph: 937-255-8648 Fax: 937-656-4547 elan.smith@wpafb.af.mil

Michael W. Garrambone, Sr. Operations Research Analyst, General Dynamics
5200 Springfield Pike, Suite 200 Dayton, Ohio 45431 Ph: 937-476-2516 Fax: 937-476-2900 mike.garrambone@gd-ais.com

Frank C. Betts, Sr. System Engineer, General Dynamics
5200 Springfield Pike, Suite 200 Dayton, Ohio 45431 Ph: 937-476-2534 Fax: 937-476-2900 frank.betts@gd-ais.com

Original title on 712 A/B: **Military SpacePlane: Ground Operations Model**

Revised title:____

Presented in (input and Bold one): (WG_**05**__, CG___, Special Session ___, Poster, Demo, or Tutorial):

This presentation is believed to be:

UNCLASSIFIED AND APPROVED FOR PUBLIC RELEASE

73rd MORS Symposium
United States Military Academy, West Point, New York
21 – 23 June 2005

Military SpacePlane: Ground Operations Model

Thomas H. Jacobs
Air Force Research Lab /
Air Vehicle Control Directorate
Wright Patterson Air Force Base, Ohio

Dr. George M. Huntley
Systems Engineering Department
US Army Logistics Management College
Fort Lee, Virginia

Elan T. Smith, Michael W. Garrambone, Frank C. Betts
General Dynamics, Dayton, Ohio

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2005**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**
4. TITLE AND SUBTITLE **Military Space Plane:Ground Operations Model**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Air Force Research Lab / Air Vehicle Control Directorate Wright Patterson Air Force Base, Ohio**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM201946, Military Operations Research Society Symposium (73rd) Held in West Point, NY on 21-23 June 2005. , The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**28**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Introduction

- MSP Ground Operations
- Problem Statement
- Modeling Considerations
- Problem Solving Approach
- Venture Evaluation Review Technique
- System Data & Analysis
- Findings & Recommendations
- Summary & POC Information

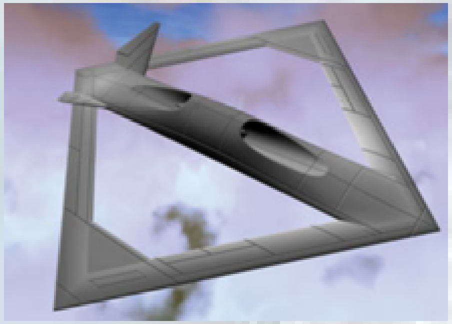
Air Vehicles Directorate

Vision

Strike UAVs

Technology Insertion

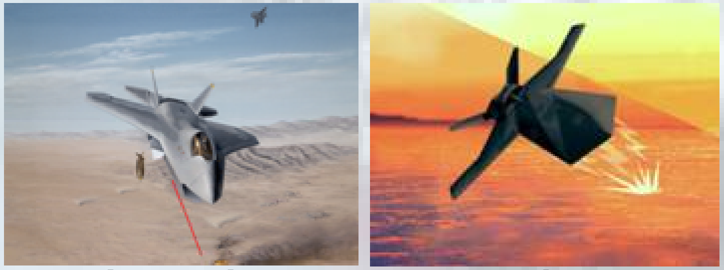
Long Range Strike



Persistent ISR

Provide the Best Air Vehicle Technologies for Aerospace Dominance

Space Operations Vehicle



Directed Energy Integration

Advanced Mobility

Directorate Mission

- Plans, formulates, and directs science & technology research for military air vehicles exploration and advanced technology development
- Orchestrates/executes technology developments in aeronautical sciences, control sciences, and aerospace structures
- Integrates systems level air vehicle technologies with other AFRL directorates. Provides technical support for aerospace systems integration
- Orchestrates technology development with other DOD and national laboratories, industries, universities, NASA, FAA, NATO, and other foreign research organizations

MSP
Military Space Plane

MSP is a reusable space taxi for carrying payloads into and from space. A space craft that embodies "aircraft-like" characteristics of current air vehicle platforms

Used for

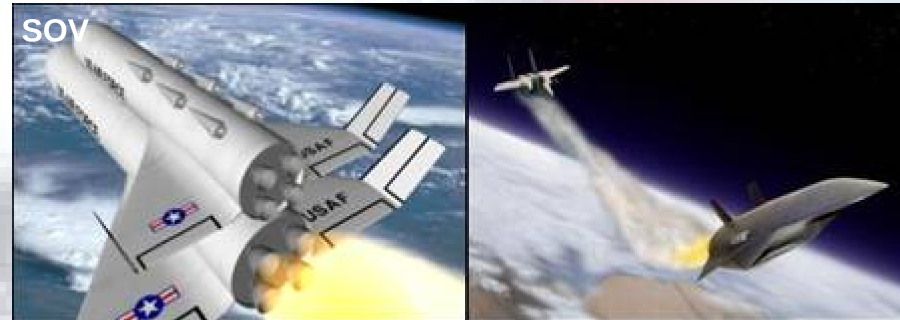
- Space Control
- Force Enhancement
- Space Support
- Force Applications

- Reusable space delivery and mission operation system
- Timely delivery of mission assets to and from space
- Multi-mission capable with interchangeable payloads
- Short-cycle, rapid mission turn around time

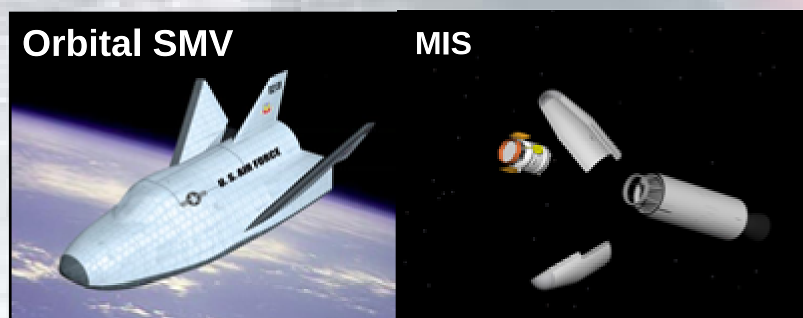
MSP Modules

Three Components

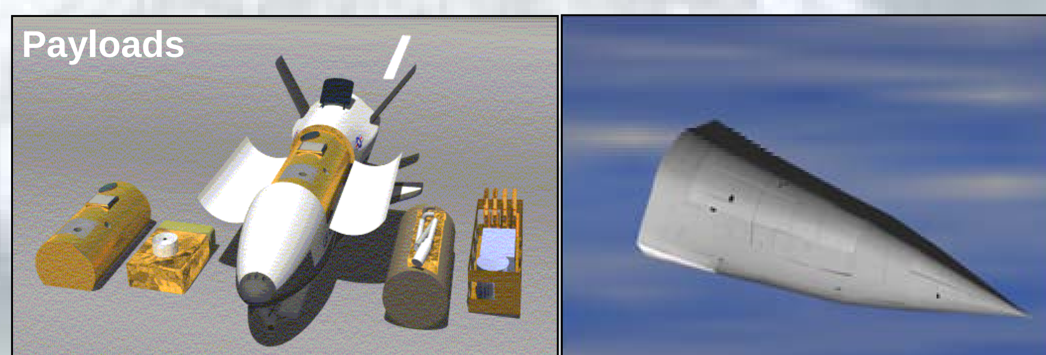
1. **Space Operations Vehicle (SOV) Reusable Booster**



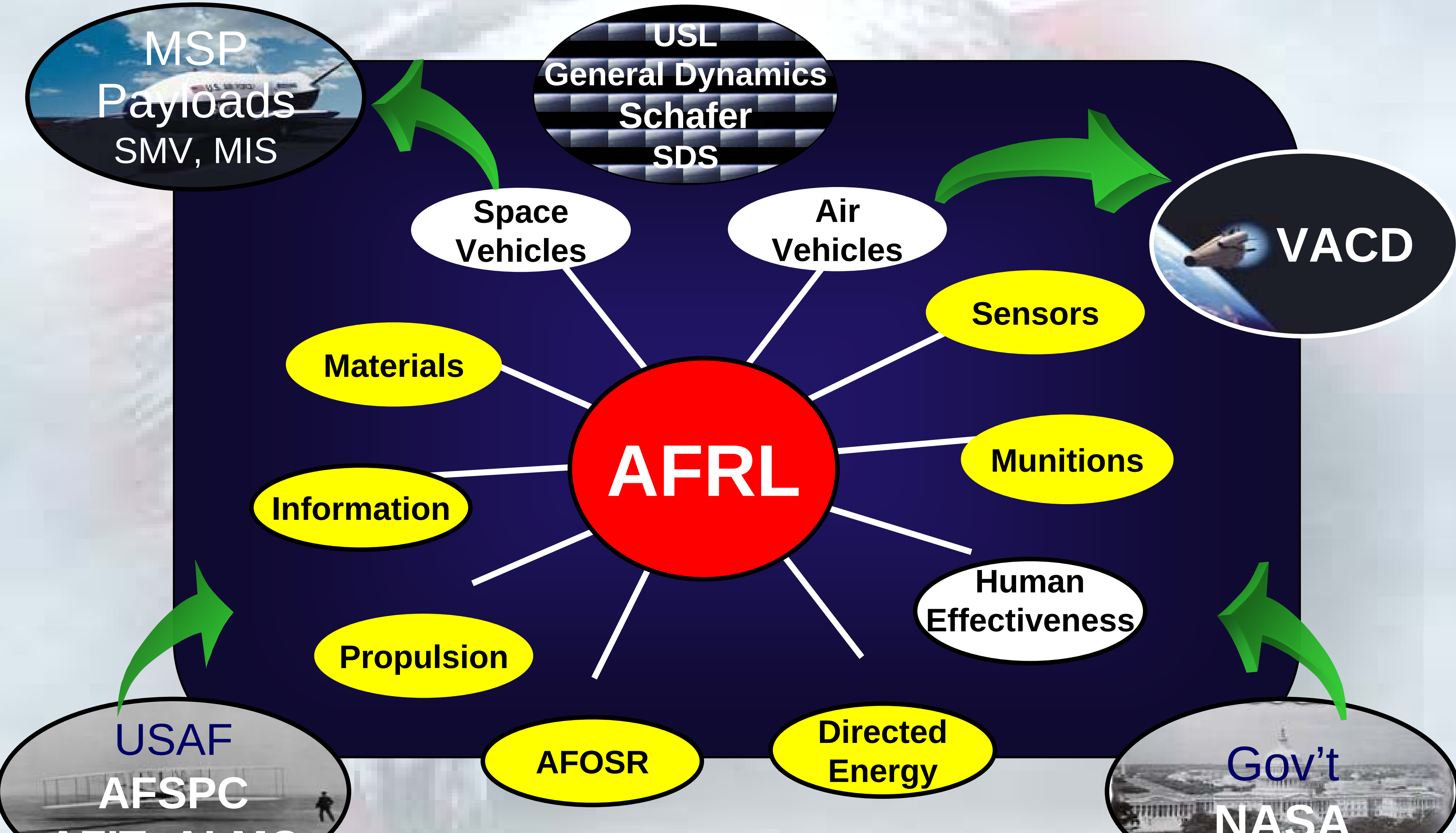
2. **Space Maneuver Vehicle (SMV) and Various Upper Stages**



3. **Various Operational and Space Mission Payloads**



Coordinating Agencies/Industries



Influenced By Many External Offices

Operationally Response Spacelift Requirements

Operationally Response Spacelift systems must be available and dependable… They must also be reliable, supportable, maintainable and robust enough to generate required mission rates… capable of meeting required turnaround-times

Mission Need Statement for Operationally Responsive Spacelift (20 Dec 01)

Need mid/far-term SS capabilities including robust and responsive space lift, rapid satellite configuration/on-orbit initialization; provide quick-turn, on-demand, assured space access for time-sensitive military operations (re-position or boost on-orbit assets)

AF Space Command Strategic Master Plan Space Support Roadmap (1 Oct 03)

During periods of war [provide] … sortie rate at least .33 sorties per day with an objective of .50 sorties per day; surge; .50 sorties per day with an objective of 1.0 sorties per day. During periods of war or exercise [provide] … turn times of 18 hours with an objective of 12 hours; surge of 12 hours with objective of 8 hours.

Systems Requirements Document for Military SpacePlane System (12 Feb 01)

Problem Statement

Background

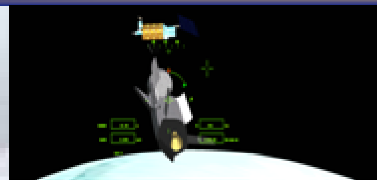
A key element in space sortie generation continues to be the ability to reduce ground operations turnaround times

Problem Statement

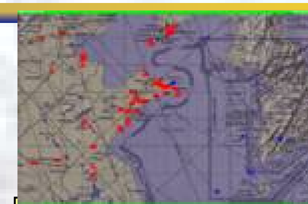
While there is data for real systems, there is little basic research on ground operations for experimental military spacelift vehicles. Turnaround information shortfall applies to processes based on engineering designs and on estimated data useful to a spacelift operation center (SOC) responsible for command and control of spacelift platforms

SAVMOS

Space Access Vehicles Mission & Operations Simulation

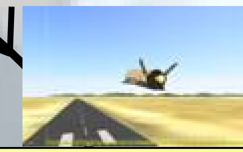


Flight Operations



Mission Operations

MSP Launch



Mission Re-Entry

Mission/Decision Support Tools

- Flight Controls
- Flight Dynamics
- System Status
- Visualization

Mission Preflight

GUI

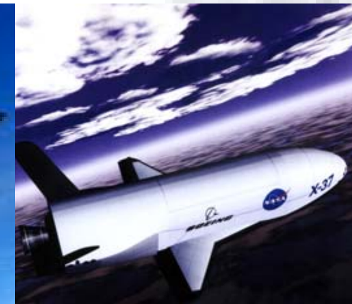
Recover & Recycle

Ground Operations

Addressing Ground Operations

Vehicle Comparisons

System →



MSP

System:	Space Shuttle	SpaceShipOne	X-37 Vehicle	B-2 Bomber	MSP
Mission:	Operational	Experimental	Experimental	Operational	TBD
Crew:	Manned	Manned	Unmanned	Manned	Unmanned
Size & weight (Payload):	Large	Small	Small	Large	Variable
Sortie Rate:	180+ days	2 < weeks	N/A	8 < hours	Goal: 8 < hrs

Ground Operations (Mission Ops)

Large and Manpower Intensive

Notional SAVMOS Facility & Crew Size

- **Minimized crew size (operational manning)**
- **Reduced facility size (footprint)**
- **Reduced cost**

Major Ground Operation Activities

Mission Return Phase 1

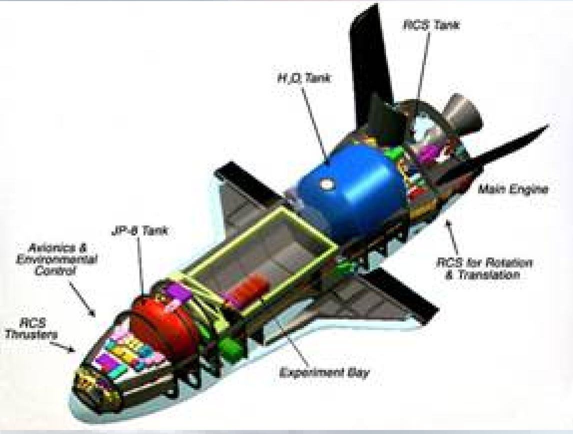
- Safe-making & moving
- Health assessment
- Post-mission Inspecting
- Payload removal
- 3 phase maintenance
- Flight Storage

Sortie Generation Phase 2

- Preflight ops checks
- Payload instantiation
- Connections & assembly
- Transport to pad
- Fueling operations
- Pre-launch preparation

Modeling Considerations

- Which operations to model (sequence major event)
- Size and scope (Fidelity) of model
- Sources of modeling information (B-2, Cape, Dryden)
- Comparative space-air data
- Data types and acquisition
- Criteria for computer model selection
- Model construction of ground operations
- Experiments with Ground Ops simulation
- Development of tools and algorithms

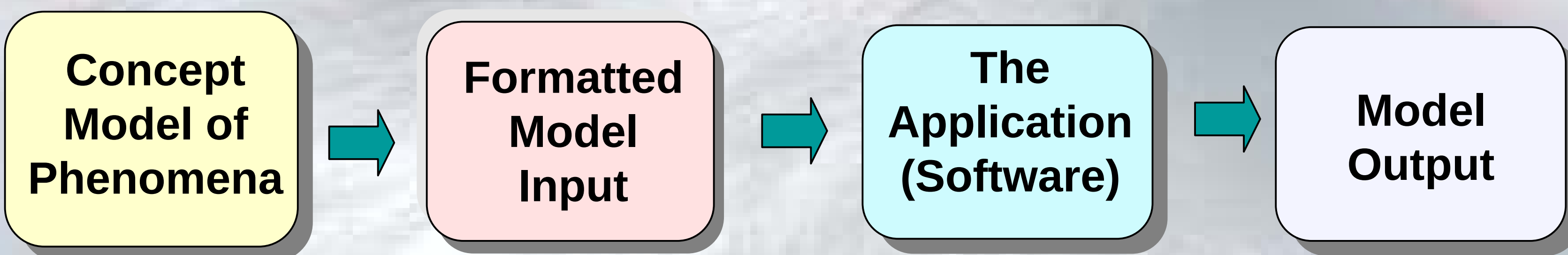


Levels and Scope of Modeling

- Spaceport Level
  - Entire space facility (all operations)
  - Every aspect of resources (A to Z)
  - Continuous flow (multi-ship operations)
- Operations Level
  - Mission operations vs. ground operations
  - Single cyclic flow of MSP(s)
  - Resources dedicated to sortie generation
- Engineering Level
  - Single ship high resolution activities
  - Craftsman level of operations
  - Detailed estimates (e.g., tile replacement)

Problem Solving Approach

- Perform phenomena research
- Determine processes and data sources
- Build a conceptual spacelift turnaround model
- Research COTS/GOTS software



- Select software and data for simulation
- Experiment with the ground ops simulation
- Analyze results and seek validation
- Refine the model and further develop tools

One Ground Operations Modeling Approach

Dr. George Huntley
Army Logistics Management College

ALMC

Army Logistics Management College

- **Trains US civilians, military, and US allies**
- **Major teaching subjects and consulting areas:**
  - **Systems Engineering (ORSA/MAC-I, Cont. Education, STS)**
  - **Logistics Courses (CLC3….)**
  - **Defense Acquisition Training (Mil. Acquisition Mgt)**
  - **Military Operations Research/Systems Analysis**
  - **Decision Risk Analysis for Engineers**
- **Resident, Onsite, Web and DL Instruction**
- **50th Anniversary in 2004**
- **Trained over quarter-million DoD students**

ALMC at Fort Lee, Virginia (www.almc.army.mil)

VERT

VERT is a network computer simulation "Engine"

- Builds greatly upon PERT/CPM but is stochastic
- Developed by Gerald L. Moeller at US Army's Rock Island Arsenal, Illinois & others since 1970s
- Used for describing & analyzing new & risky projects
- Uses time, cost, performance, & probabilities to evaluate alternatives
- Free for US Govt use & easy to Learn
- Proponent: US Army Log. Mgt. College, Ft Lee, VA

General VERT Use

Great for analyzing small to moderately complex projects

- **Historically used to**
  - **Develop new weapons systems**
  - **Generate independent cost estimates**
  - **Effects of chemical demilitarization**
  - **Estimate logistics problems of simultaneously fighting several limited world conflicts**
  - **Plan reactivation of "Mothballed" facilities**
  - **Other efforts (reliability, design, safety)**

VERT Strengths & Limitations

- Strengths
  - Graphical formulation converts to arcs and nodes with data
  - Easy to learn, formulate model, and instantiate
  - Provides quick turn simulation runs
  - Automatically provides useful statistical output
  - Price is A-OK, ALMC is sponsor
- Limitations
  - Can be unwieldy with gigantic projects
  - NO "looping back" to previous part of network
  - PC Version 3.7 limited to 350 arcs/200 nodes/1000 iterations
  - Only 20 internal/10 terminal node, 20 slack histograms
  - PC Version needs VV&A on queue and time phasing
  - Minimal "user friendly" features (DOS like)

VERT 101

Arcs are Activities

Arcs not Orcs

From Node — Tying your shoe — To Node

Prob of success

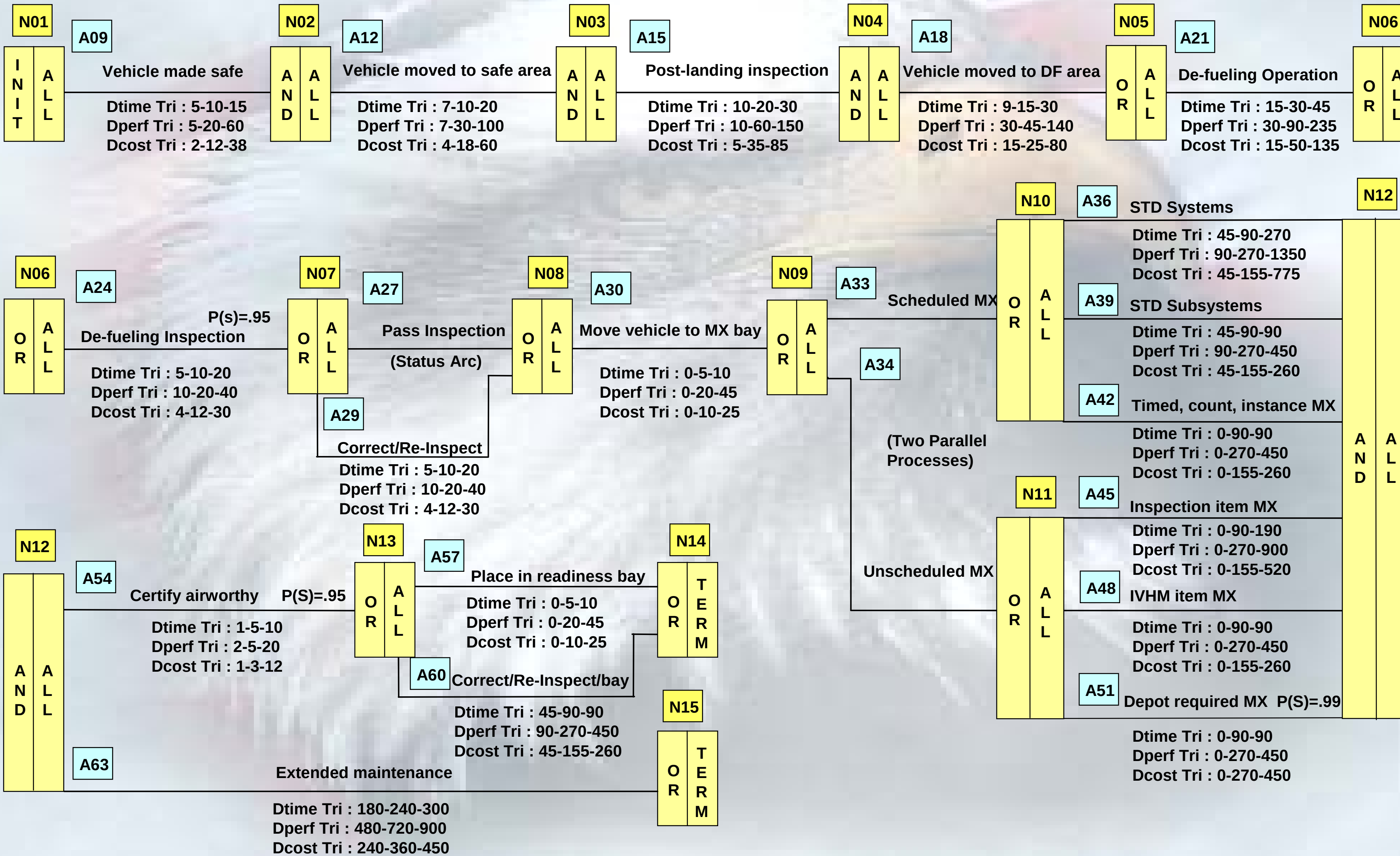
Time(T)/Cost(C) /Performance(P) Estimates

Nodes are conditional branch points or decision logic points

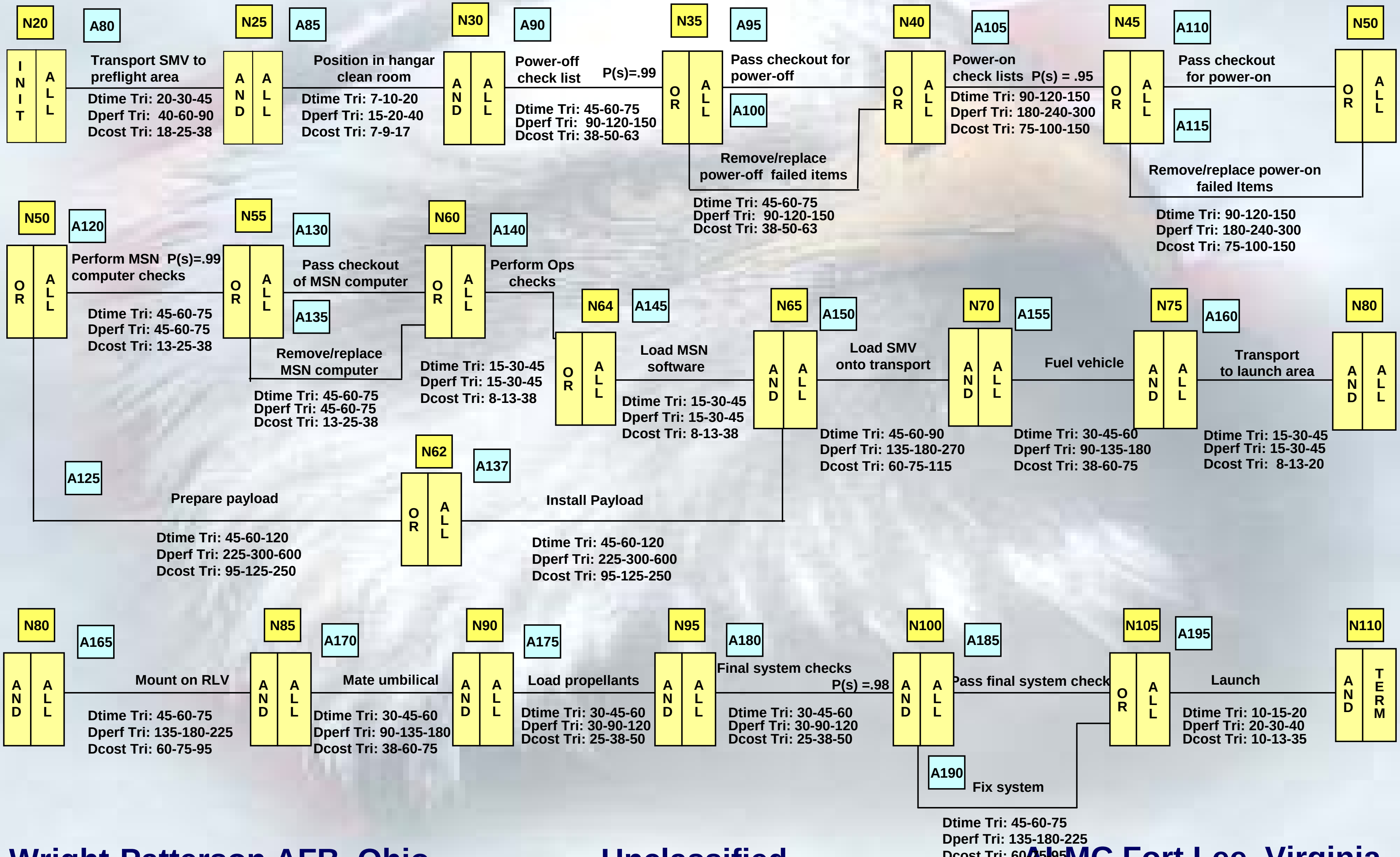
Start | Terminate | And | Or | Compare T/C/P | Waiting Queue

Some Example VERT Nodes

Post-Landing



Pre-Launch



N20
A80
INIT
ALL
Transport SMV to preflight area
Dtime Tri: 20-30-45
Dperf Tri: 40-60-90
Dcost Tri: 18-25-38
N25
A85
AND
ALL
Position in hangar clean room
Dtime Tri: 7-10-20
Dperf Tri: 15-20-40
Dcost Tri: 7-9-17
N30
A90
AND
ALL
Power-off check list
P(s)=.99
Dtime Tri: 45-60-75
Dperf Tri: 90-120-150
Dcost Tri: 38-50-63
N35
A95
OR
ALL
Pass checkout for power-off
A100
Remove/replace power-off failed items
Dtime Tri: 45-60-75
Dperf Tri: 90-120-150
Dcost Tri: 38-50-63
N40
A105
OR
ALL
Power-on check lists P(s) = .95
Dtime Tri: 90-120-150
Dperf Tri: 180-240-300
Dcost Tri: 75-100-150
N45
A110
OR
ALL
Pass checkout for power-on
A115
Remove/replace power-on failed Items
Dtime Tri: 90-120-150
Dperf Tri: 180-240-300
Dcost Tri: 75-100-150
N50
OR
ALL
N50
A120
OR
ALL
Perform MSN computer checks
P(s)=.99
Dtime Tri: 45-60-75
Dperf Tri: 45-60-75
Dcost Tri: 13-25-38
N55
A130
OR
ALL
Pass checkout of MSN computer
A135
Remove/replace MSN computer
Dtime Tri: 45-60-75
Dperf Tri: 45-60-75
Dcost Tri: 13-25-38
N60
A140
OR
ALL
Perform Ops checks
Dtime Tri: 15-30-45
Dperf Tri: 15-30-45
Dcost Tri: 8-13-38
N64
A145
OR
ALL
Load MSN software
Dtime Tri: 15-30-45
Dperf Tri: 15-30-45
Dcost Tri: 8-13-38
N65
A150
AND
ALL
Load SMV onto transport
Dtime Tri: 45-60-90
Dperf Tri: 135-180-270
Dcost Tri: 60-75-115
N70
A155
AND
ALL
Fuel vehicle
Dtime Tri: 30-45-60
Dperf Tri: 90-135-180
Dcost Tri: 38-60-75
N75
A160
AND
ALL
Transport to launch area
Dtime Tri: 15-30-45
Dperf Tri: 15-30-45
Dcost Tri: 8-13-20
N80
AND
ALL
A125
Prepare payload
Dtime Tri: 45-60-120
Dperf Tri: 225-300-600
Dcost Tri: 95-125-250
N62
A137
OR
ALL
Install Payload
Dtime Tri: 45-60-120
Dperf Tri: 225-300-600
Dcost Tri: 95-125-250
N80
A165
AND
ALL
Mount on RLV
Dtime Tri: 45-60-75
Dperf Tri: 135-180-225
Dcost Tri: 60-75-95
N85
A170
AND
ALL
Mate umbilical
Dtime Tri: 30-45-60
Dperf Tri: 90-135-180
Dcost Tri: 38-60-75
N90
A175
AND
ALL
Load propellants
Dtime Tri: 30-45-60
Dperf Tri: 30-90-120
Dcost Tri: 25-38-50
N95
A180
AND
ALL
Final system checks
P(s) =.98
Dtime Tri: 30-45-60
Dperf Tri: 30-90-120
Dcost Tri: 25-38-50
N100
A185
AND
ALL
Pass final system check
A190
Fix system
Dtime Tri: 45-60-75
Dperf Tri: 135-180-225
Dcost Tri: 60-75-95
N105
A195
OR
ALL
Launch
Dtime Tri: 10-15-20
Dperf Tri: 20-30-40
Dcost Tri: 10-13-35
N110
AND
TERM

Network Results

Post-Return	Arc/Nodes	Key Probabilities (Notional)	Hour	%
Sch/Unsch MX	21 Activities	.95 De-fuel ops	4.45 *	98
MX Delay	15 Decision Points	.99 No depot MX .95 Cert. inspection	7.86 *	02

Pre-Launch	Arc/Nodes	Key Probabilities (Notional)	Hour	%
Preparation, test, & payload	25 Activities 21 Decision Points	.95 Power off check .95 Power on check .99 Computer check .99 Final System check	12.2 *	100

Post-Return thru Pre-Launch	Arc/Nodes	Key Probabilities (Notional)	Hour	%
All activities * Results are from Notional Inputs	47 Activities 34 Decision Points	Same probabilities as above	16.6 *	100

Findings & Recommendations

- Findings
  - Large amount of time devoted to moving, racking, and stacking
  - Small Prob of failure results in dramatic decreases in time & cost
  - Payload preparation has to be a parallel activity (racks)
  - Goal is to avoid depot maintenance delays (spares)
  - Estimates employed in this draft are highly optimistic
  - Model assumed unlimited use of working spaceport resources
- Recommendations
  - Continue work on validation of changing processes (TPS, IVHM)
  - Obtain better data on maintenance tests and durations
  - Move to a more sophisticated computer model when spaceport and vehicle operational data becomes available

Points-Of-Contact

Thomas H. Jacobs
Air Force Research Lab / Air Vehicle Control Directorate
Wright Patterson Air Force Base, Ohio
Phone: 937 - 904 - 6520 DSN: 674 - 6520
Fax: 937 - 255 - 9746 DSN: 785 - 9746
Email: thomas.jacobs@wpafb.af.mil

Dr. George M. Huntley
Systems Engineering Department
Army Logistics Management College, Fort Lee, Virginia
Phone: 804 - 765 - 4265 DSN: 539 - 4265
Fax: 804 - 765 - 4648 DSN: 539 - 4648
Email: george.huntley@us.army.mil