Expert Systems for Assembly Sequence Evaluation

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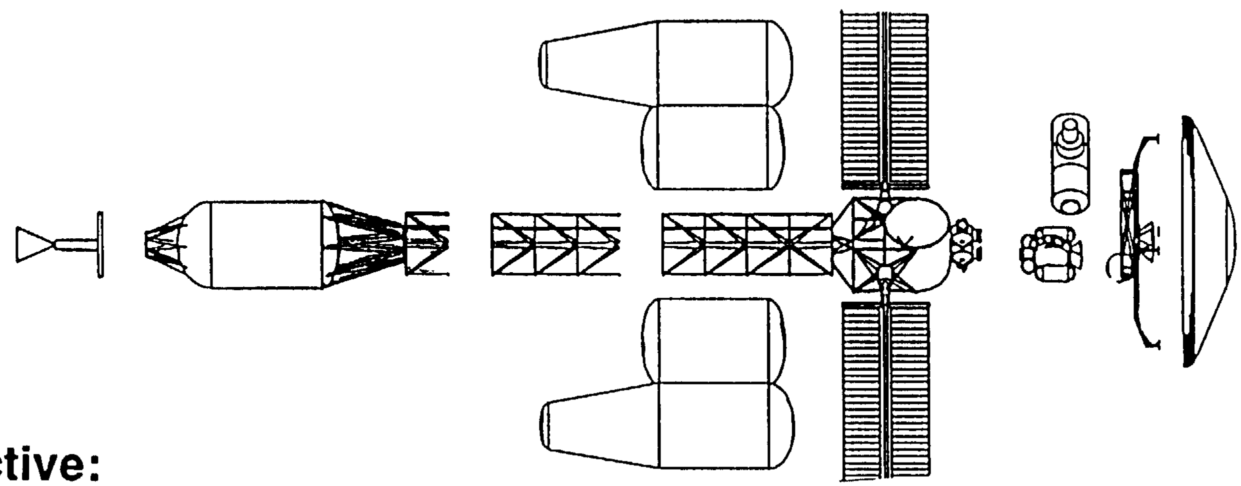
EXPERT SYSTEMS FOR ASSEMBLY SEQUENCE EVALUATION

PRESENTATION FOCUS:

- ❑ RESEARCH GOALS
- ❑ METHODOLOGIES
- ❑ RESULTS
- ❑ CONCLUSIONS & PLANS

RESEARCH GOALS

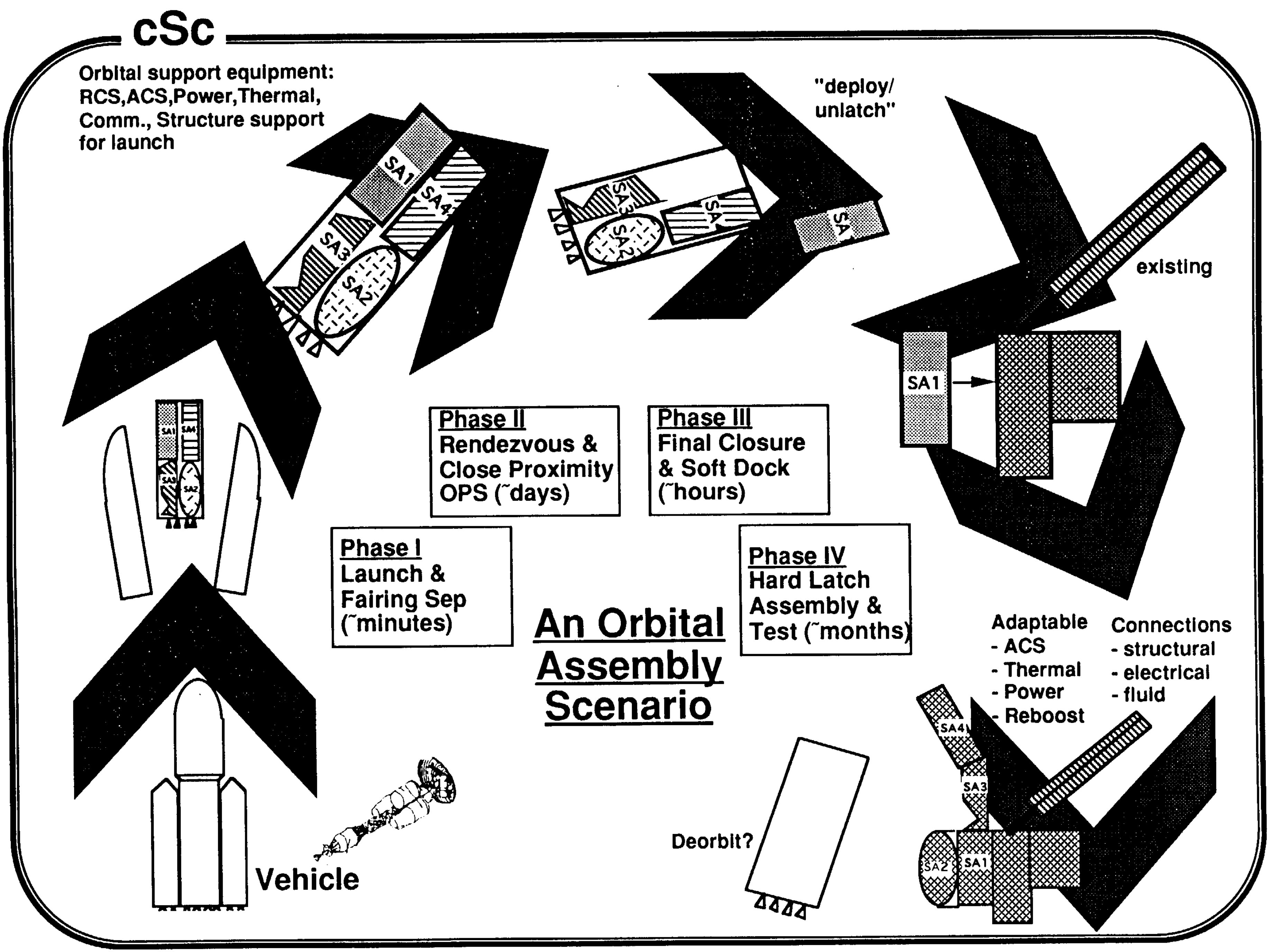


Objective:

Identify delivered orbital subassemblies derived from a Phase A conceptual space vehicle design while minimizing on-orbit assembly complexity.

Primary Constraints:

- ❑ Payload Shroud mass and volume (allowing for rendezvous stage)
- ❑ Geometric Feasibility
- ❑ Connection-technology Limitation
- ❑ Tool Performance Limitations
- ❑ Minimal Crew Hazard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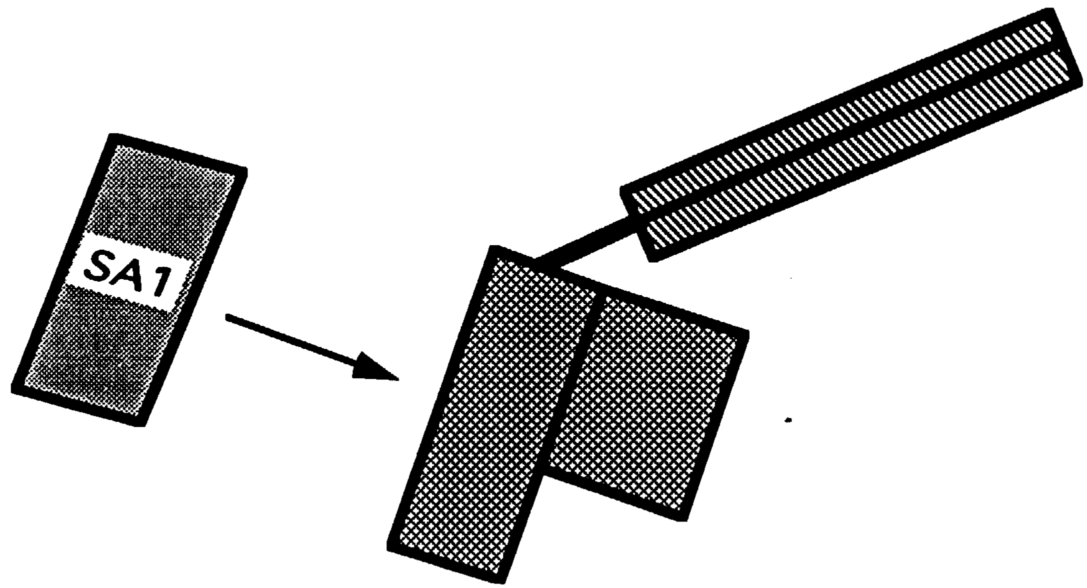
Orbital support equipment:
RCS,ACS,Power,Thermal,
Comm., Structure support
for launch
SA1
SA4
SA3
SA2
"deploy/
unlatch"
existing
Phase II
Rendezvous &
Close Proximity
OPS (~days)
Phase III
Final Closure
& Soft Dock
(~hours)
Phase I
Launch &
Fairing Sep
(~minutes)
An Orbital
Assembly
Scenario
Phase IV
Hard Latch
Assembly &
Test (~months)
Adaptable
- ACS
- Thermal
- Power
- Reboost
Connections
- structural
- electrical
- fluid
Deorbit?
Vehicle

SUBASSEMBLIES

Attributes

- Geometric Characteristics
- Special Hazards
- Inertial Properties
- Control Response
- Engineering Subsystems
- External Interfaces



A Beginning Taxonomy of Subassemblies:

Tanks	Crew
Partial Spacecraft	Avionics
Complete Spacecraft	Propulsion
Structural	Power

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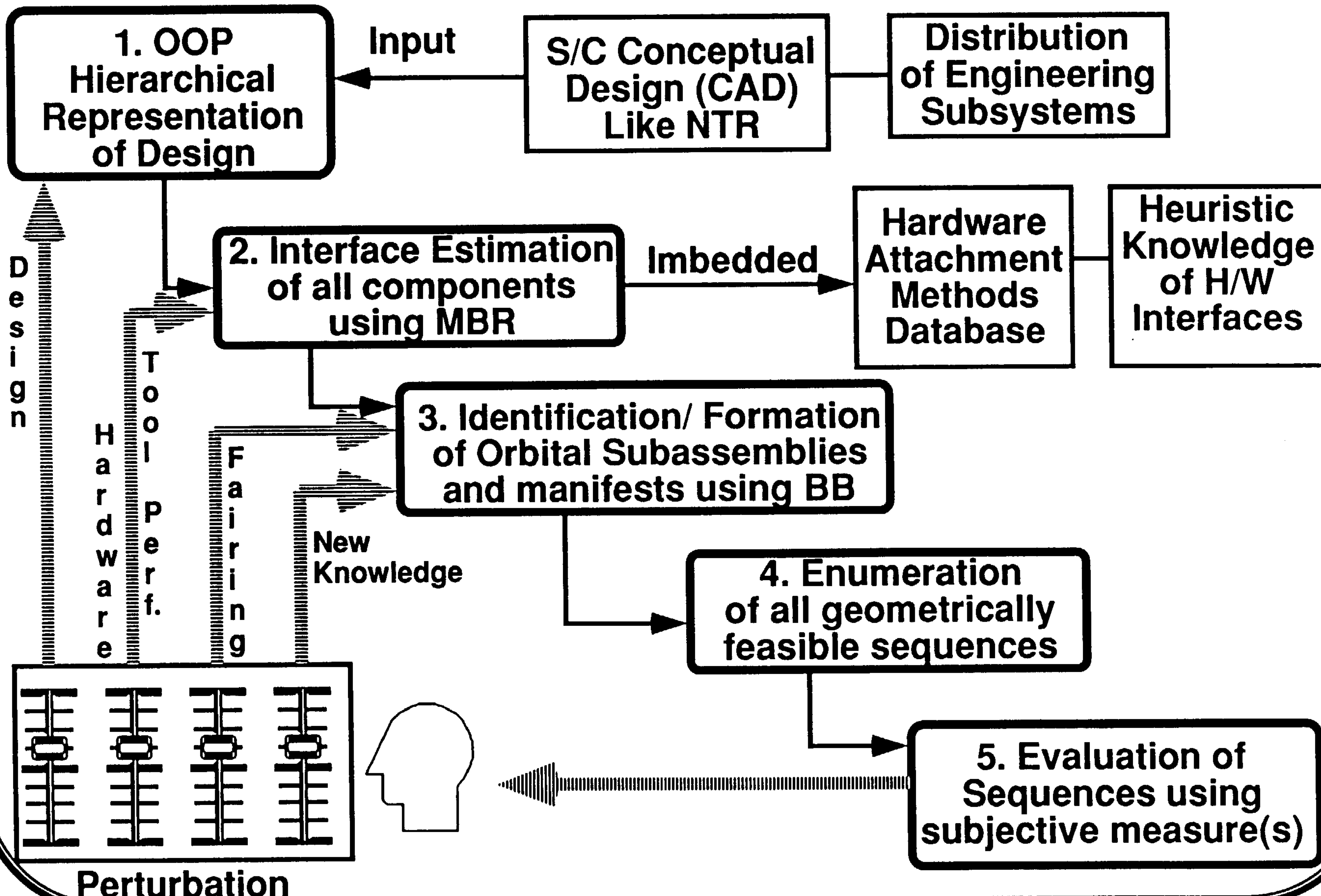
SUBASSEMBLY IDENTIFICATION SIMULATION MODEL



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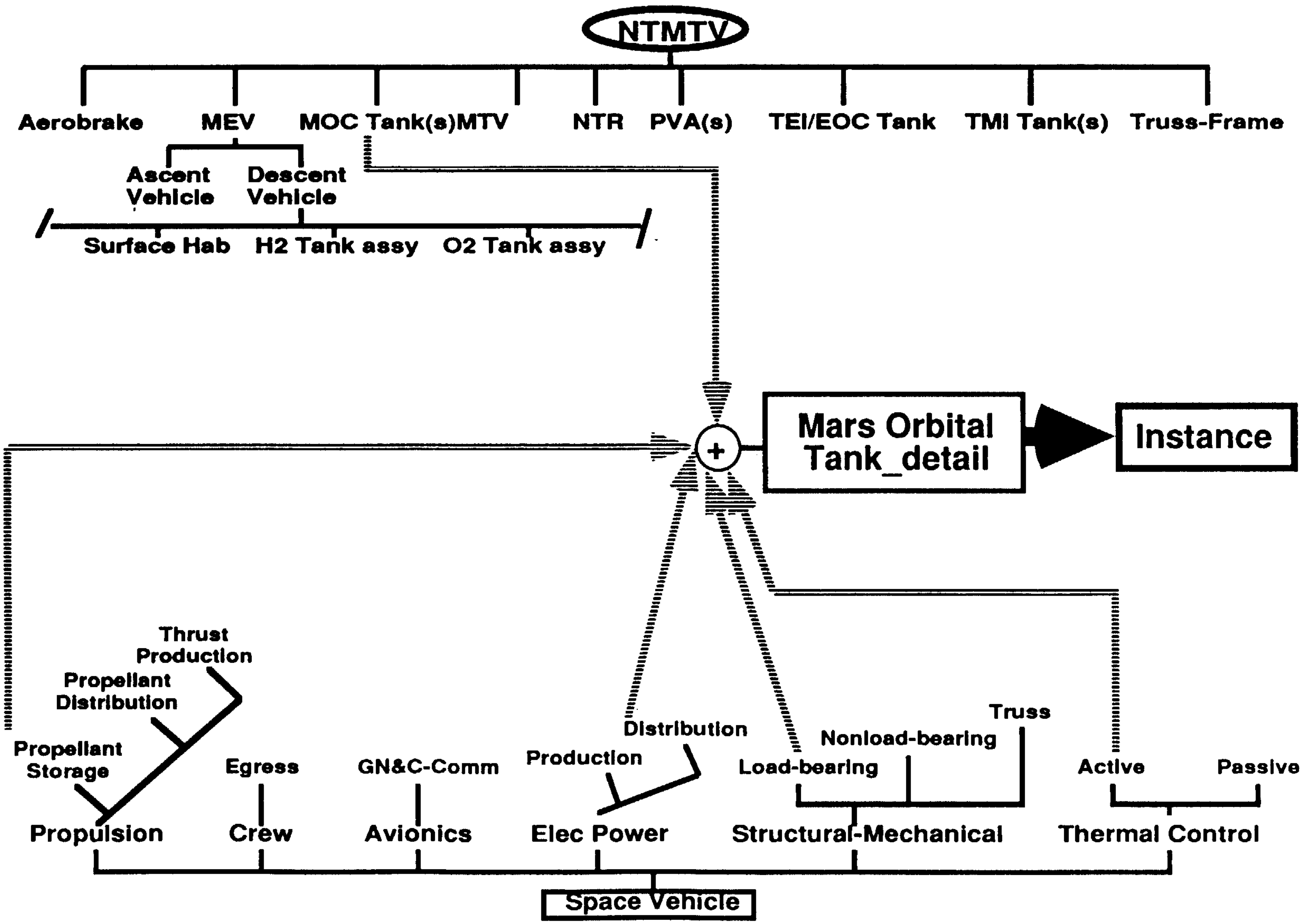
ESTIMATING SUBASSEMBLY INTERFACES BY ENGINEERING FUNCTIONAL ALLOCATION USING MBR



REPRESENTATIVE DATA BASE OF INTERFACE CONNECTIONS

- Should reflect current Aerospace Industry practice, but can be upgraded for in-space construction connection technologies
- Each type of attachment method has codes which indicate the capabilities and constraints of such method
- A representative normalized "index" of connection difficulty has been ascribed using MIL-Std Handbook-472 (Maintainability) TER's and MDSSC inspection and testing company standards, as penalties
- Data base is not yet rigorous, nor has it been modified for in-space construction, but it is a starting point
- Desperately need data on human EVA interface connection primitives

Cleanliness Codes:

L- LOX Clean
F- Fuel Clean
E- Electrical Clean
H- Hydraulic Clean
B- Biologically Clean

Insp/ Ver Codes:

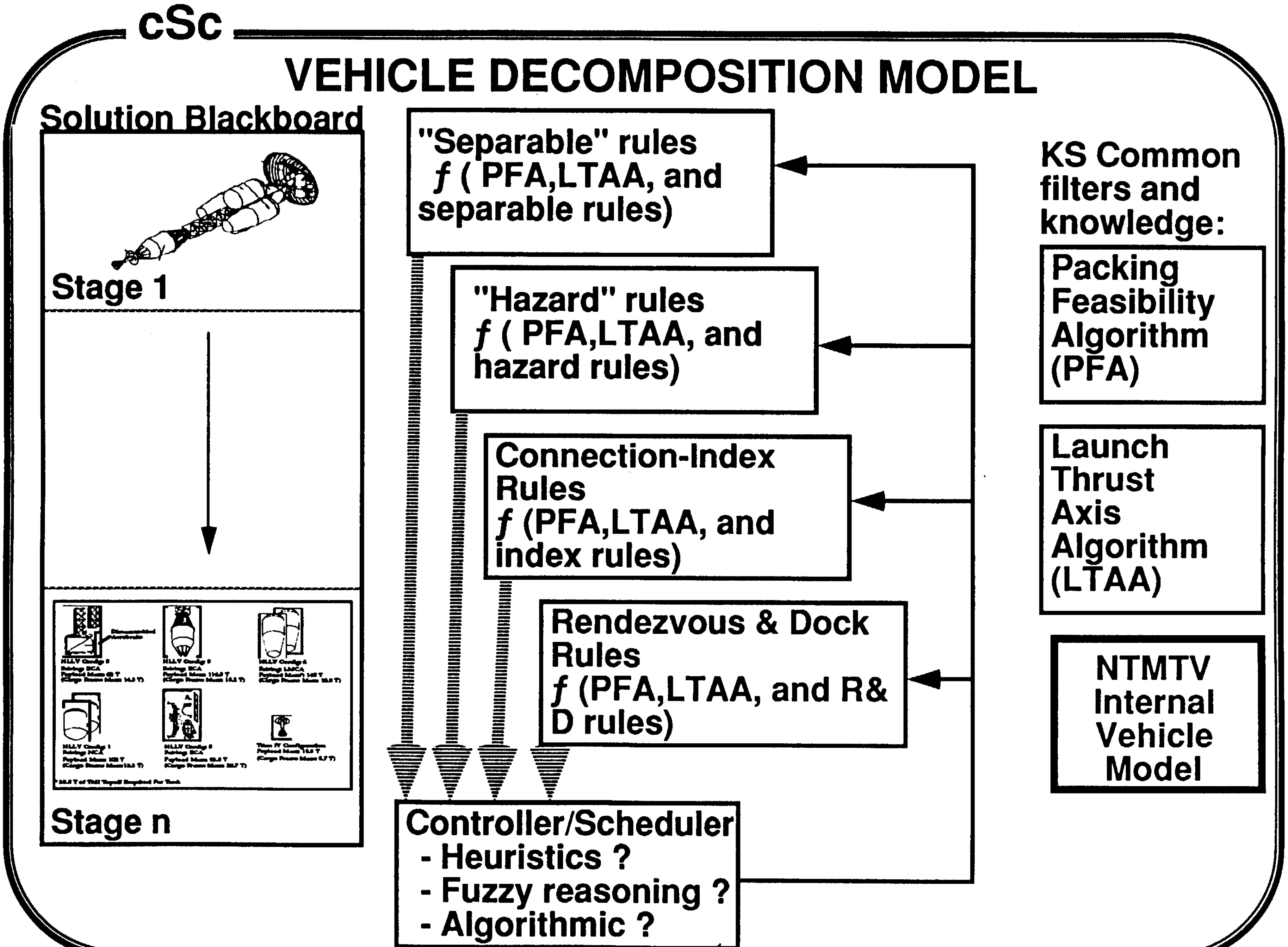
V- Visual
M- Mechanical
L- Leak Check
E- Electrical
A- Automatic
X- X-ray
U- Ultrasonic

Process Physics Codes:

T- Thermal Producing
O- Outgassing
C- Caustic/contaminating solvents
E- Electromagnetic Interference
V- Vibration/shock
S- Electrostatic
D- Debris/projectile

Temporal Codes:

I- Instantaneous
F- Fast setting, < 1 minute
M- Medium setting, < 30 minutes
S- Slow setting, > 30 minutes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VEHICLE DECOMPOSITION MODEL
Solution Blackboard
Stage 1
Stage n
"Separable" rules
ƒ (PFA,LTAA, and separable rules)
"Hazard" rules
ƒ (PFA,LTAA, and hazard rules)
Connection-Index Rules
ƒ (PFA,LTAA, and index rules)
Rendezvous & Dock Rules
ƒ (PFA,LTAA, and R& D rules)
Controller/Scheduler
- Heuristics ?
- Fuzzy reasoning ?
- Algorithmic ?
KS Common filters and knowledge:
Packing Feasibility Algorithm (PFA)
Launch Thrust Axis Algorithm (LTAA)
NTMTV Internal Vehicle Model

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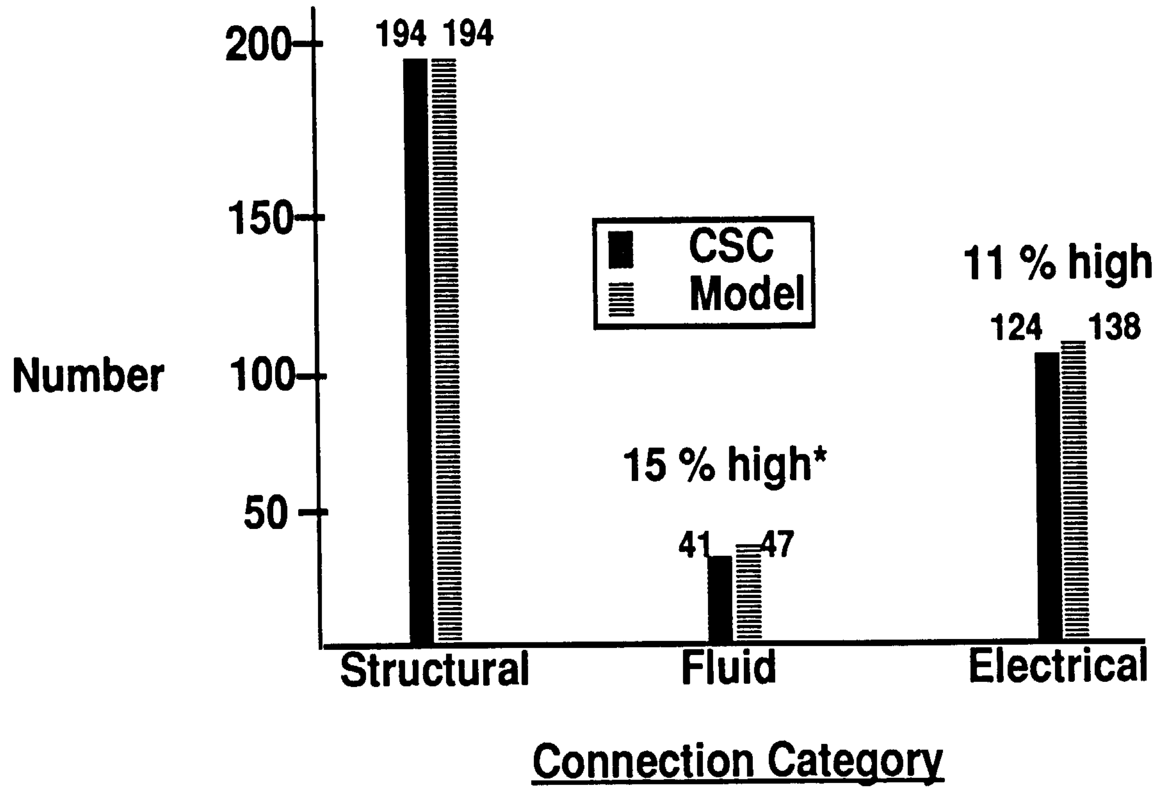
CONNECTION INTERFACE ESTIMATION MODEL RESULTS

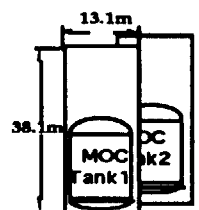


Mars Vehicle Interface Estimation Results, Model vs. CSC study

Total Connections (10 Subassemblies, Boeing NTR-2016) = 379

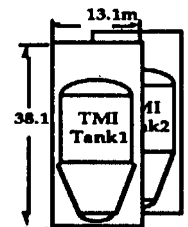
KNOWLEDGE-SOURCE 1 AND 2 RESULTS

KS1



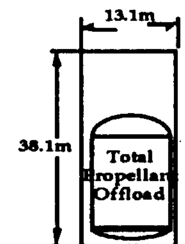
Subassembly mass = 88.59 metric tons
Mass efficiency = 69.76 %
Volumetric efficiency = 26 %

+



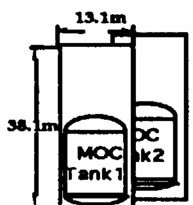
Subassembly mass = 110.5 metric tons
Mass efficiency = 87 %
Volumetric efficiency = 45.88 %

+



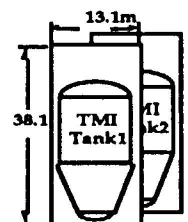
Subassembly mass = 108 metric tons
Mass Efficiency = 85 %
Volumetric efficiency = not calculated

KS2



Subassembly mass = 88.59 metric tons
Mass efficiency = 69.76 %
Volumetric efficiency = 26 %

+



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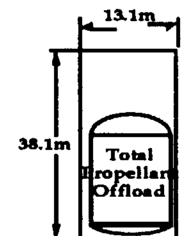

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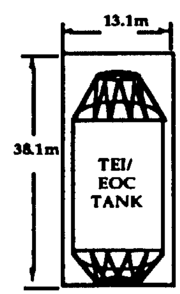

Subassembly mass = 100.33 metric tons
Mass efficiency = 79 %
Volumetric efficiency = 53.53 %

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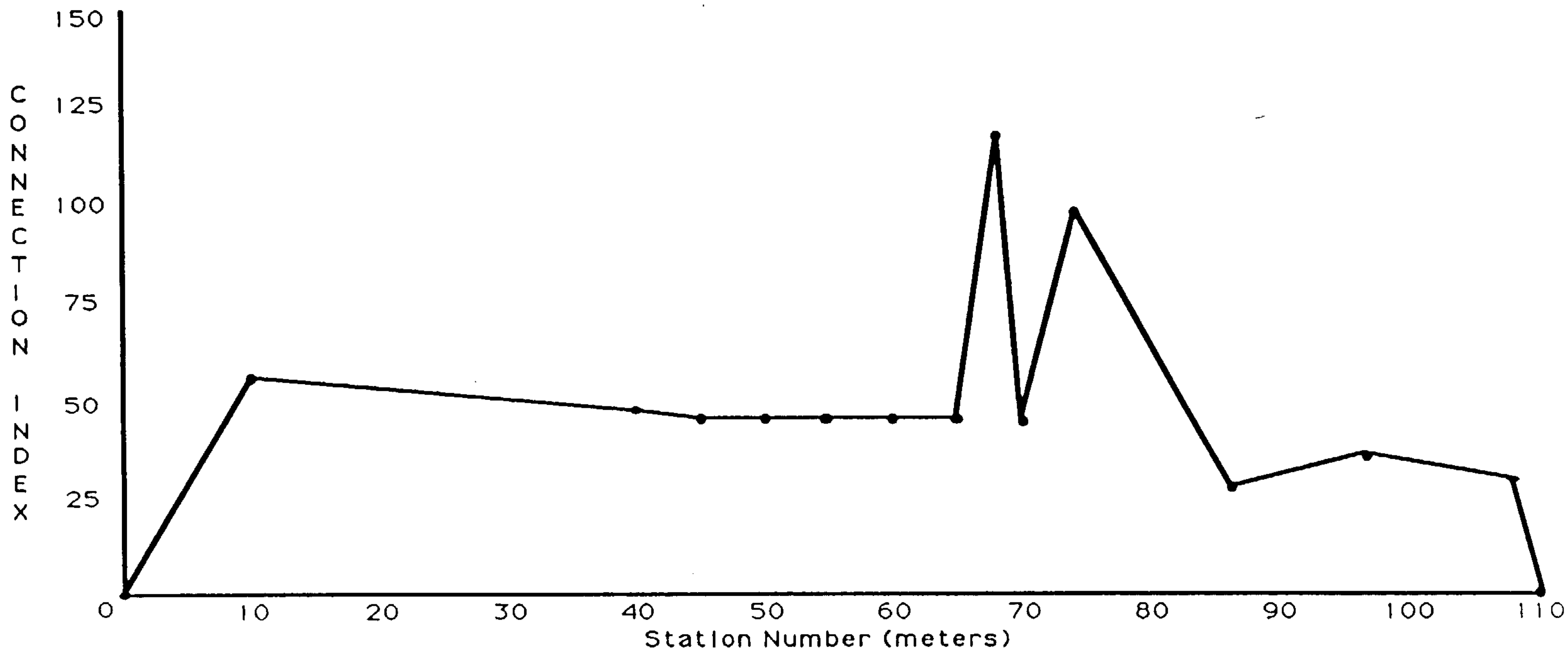
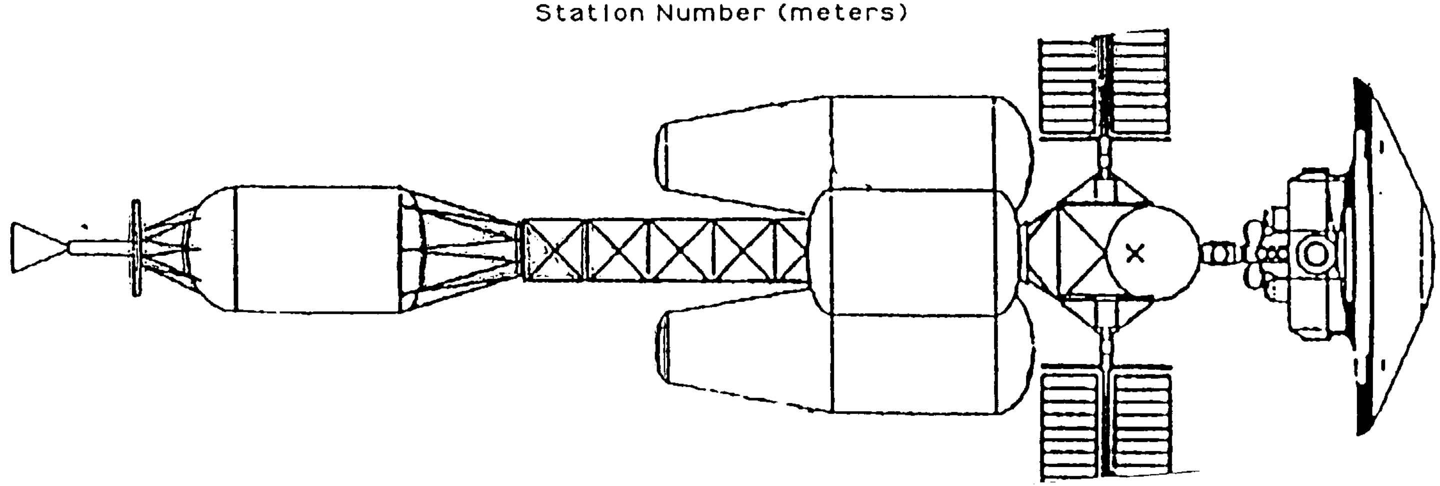
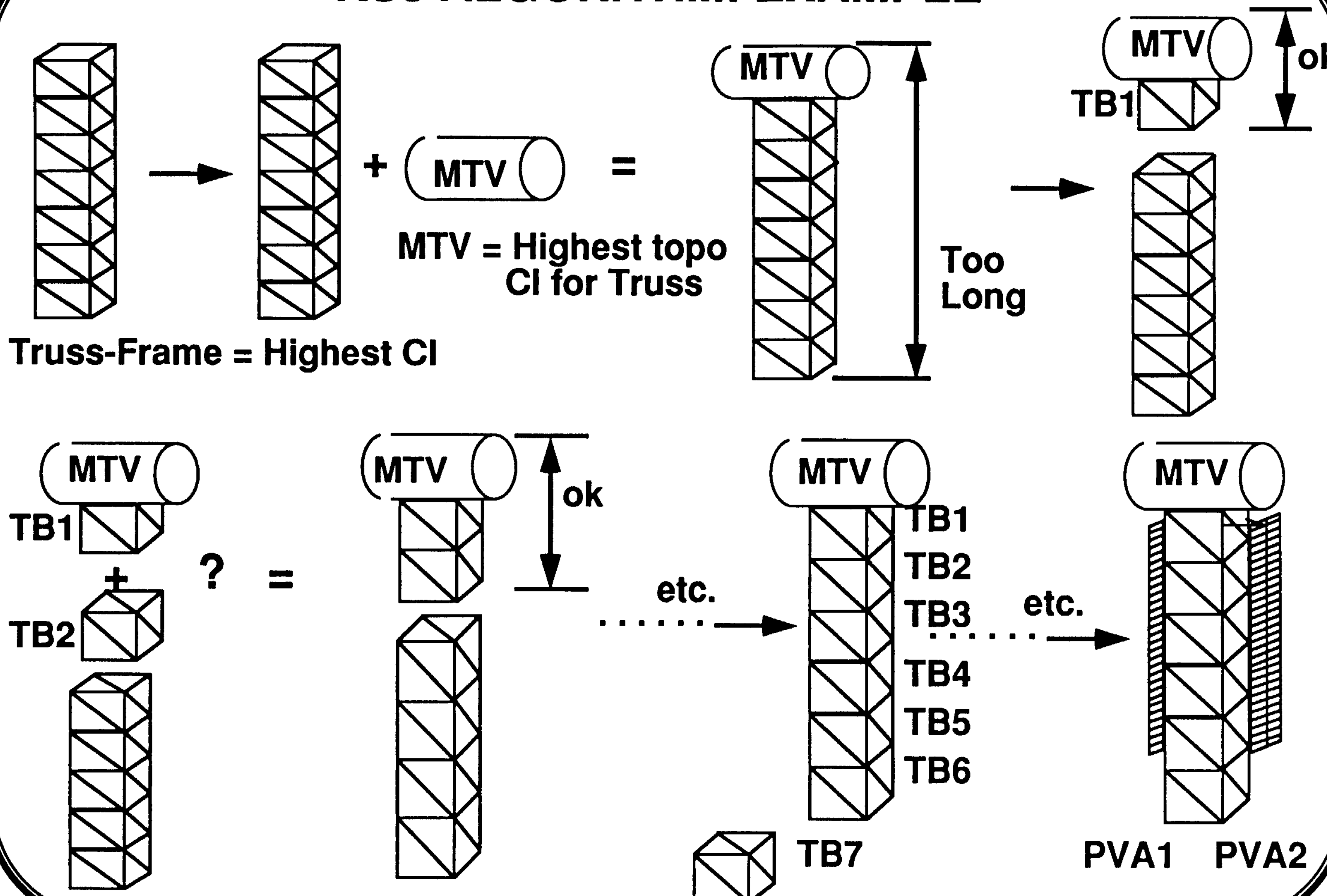
KNOWLEDGE-SOURCE 3 =====> CONNECTION-INDEX RESULTS: BOEING NTR-2016 CI-PROFILE



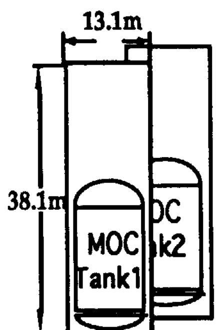


KS3 ALGORITHM: EXAMPLE



KS3: Flight Manifest Results

- Two New Aggregates Created
- True Synthesis



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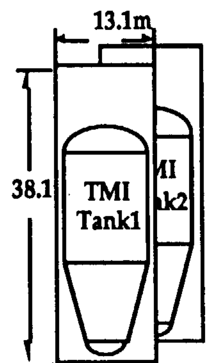

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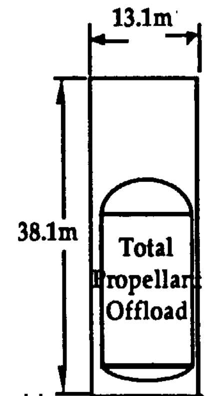

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Volumetric efficiency = not calculated

New Subassembly 2 (TEI/EOC Tank + Truss-Bay 1)

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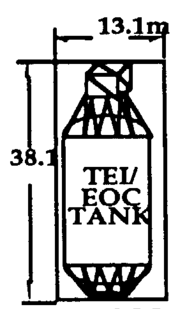

Subassembly mass = 100.33 metric tons
Mass efficiency = 79 %
Volumetric efficiency = 53.53 %

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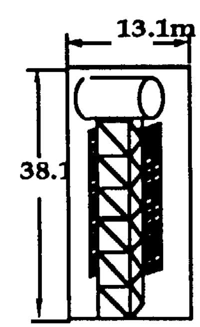
New Subassembly 1 (MTV + Truss-Bays 1-6 + PVAs 1 & 2)



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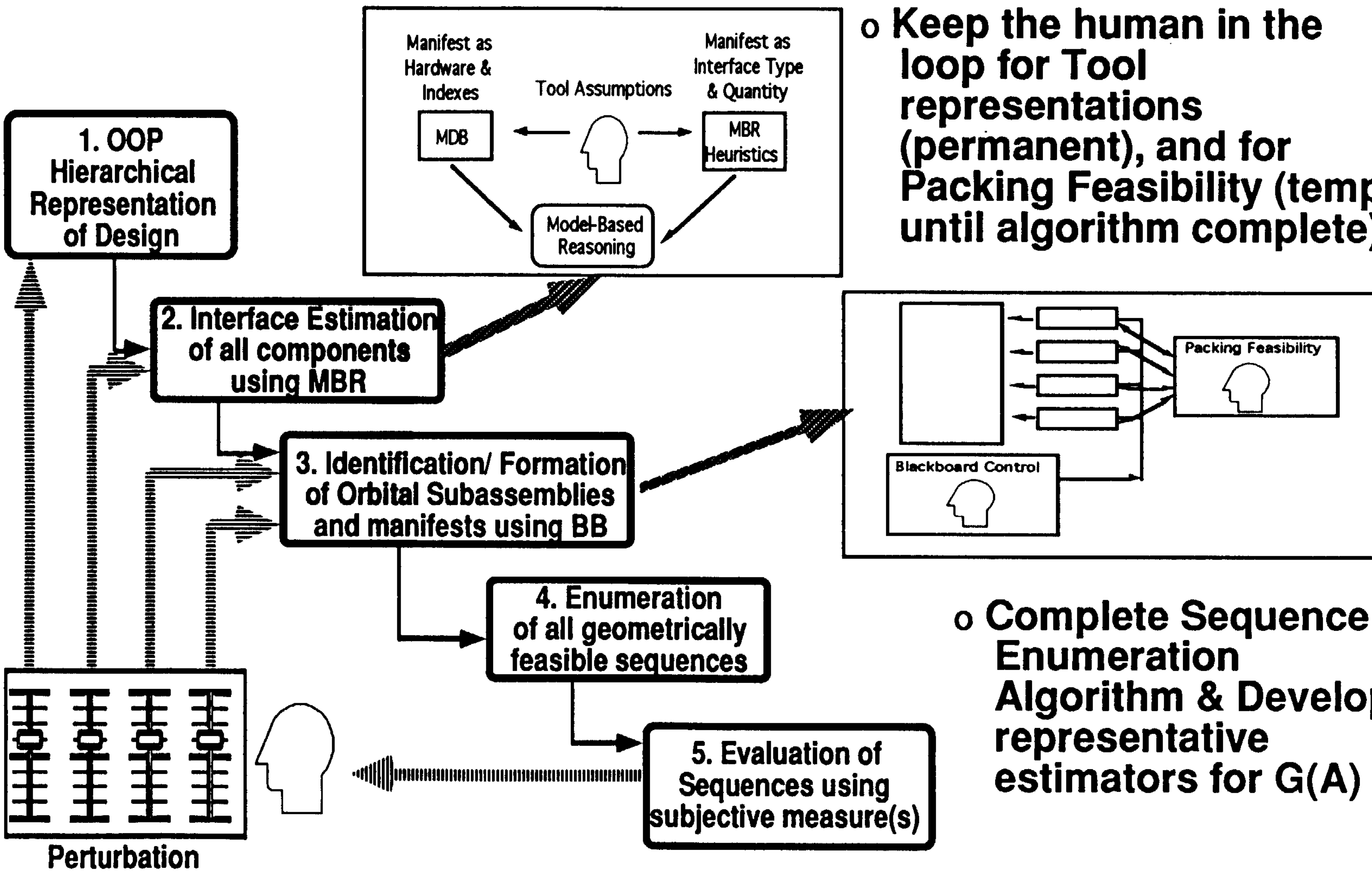
Conclusions and Plans



- Keep the human in the loop for Tool representations (permanent), and for Packing Feasibility (temp. until algorithm complete)
- Complete Sequence Enumeration Algorithm & Develop representative estimators for G(A)
- Evaluate simulation stability through perurbation analyses of inputs, and introduction of other orbital assembly designs