



# Platform Analysis Perspective

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## Objective of Paper

- To present a kind of operational architecture suitable for integrated weapons analysis
- To see how the elements change as a mission progresses
- To see how the structure must be built from the desired mission outcome back towards platform design
- To extend the process to a system-of-systems



## Key Metrics

**There are three principal weapons platform metrics:**

**Level 4], *Platform Utility*, which is derived from**

**Level 3], *Platform Capability*, which is derived from**

**Level 2], *Platform Componentry/Connectivity*, which is the fundamental platform metric.**





# Key Platform Metrics

These metrics are the

**WHY**

**(Level 4]**

the

**WHAT**

**(Level 3]**

and the

**HOW**

**(Level 2]**

of an **operations research** framework.



# Example: Platform Configuration

Level 2]

Secondary Armament

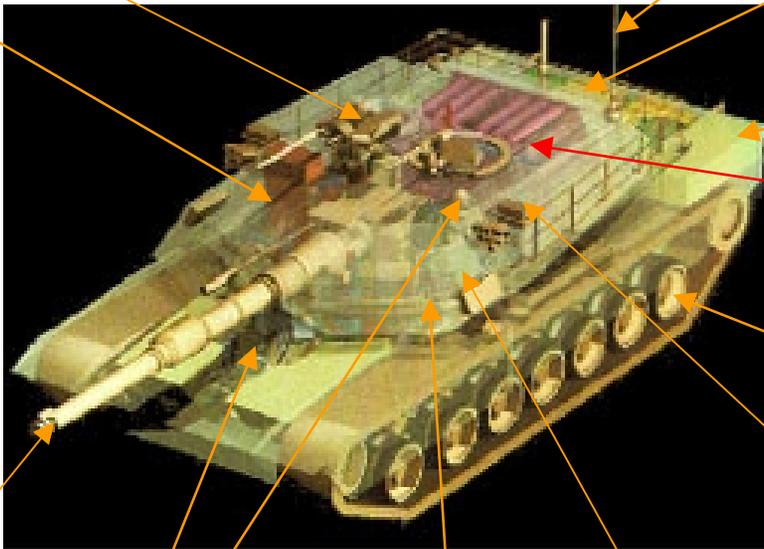
Early Warning Sensors  
(LWR, RWR, MWR)

Move

Shoot

Communicate

Main Armament



Commo Equipment

Engine Compartment

Fuel

Ammo Compartment

Wheels/Track

Commo Equipment

Target Acquisition/Engagement Sights

Crew

Millimeter Wave Radar Antenna

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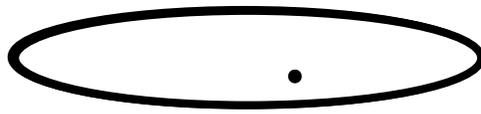
# Abstraction: Platform Configuration

Level 2]

Military  
Operations  
Context

- Tactics
  - Doctrine
  - Scenario
  - etc.
- (Global Variables)

Level 2]



$v_2[C_1, C_2, \dots, C_e, C_d, \dots, C_j, C_k, \dots, C_m, C_n]$

Crew      Ammo      Fuel      Msn Crit

Re-Armed and Re-Fueled

H + 7

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# Testing for Platform Capabilities

Level 3]

Move

Communicate

Sense



Engage

Replenish

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# Abstraction: Platform Capabilities

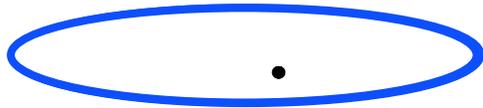
## Level 3]

$v_3$ [Top Speed, Max Range, Rough Terrain Capability, ...  
Rate of Fire, Time to Acquire Tgt, Hit Dispersion, ...  
Data Rate, Data Latency, ...]

Military Operations Context

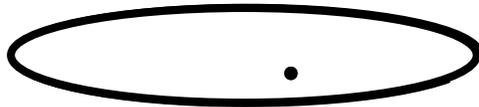
- Tactics
  - Doctrine
  - Scenario
  - etc.
- (Global Variables)

Level 3]

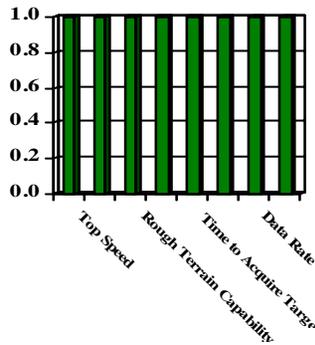


$O_{2,3}$  Operator

Level 2]



Context Data



H + 7



# Mission Utility from Capabilities

Level 4]

Effectiveness?

Performance?

Lethality?



Survivability?

Loss/Exchange?

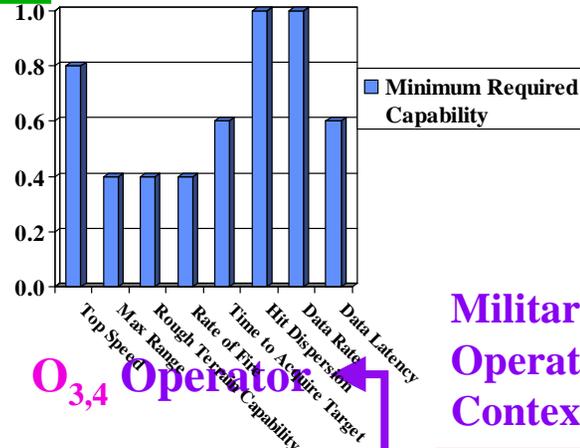
Readiness?

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# Abstraction: Platform Utility

## Level 4]



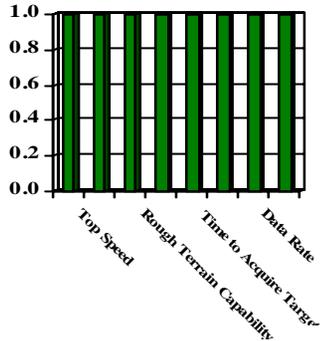
Level 4]



O<sub>3,4</sub> Operator  
Msn Cap Reqs

Military Operations Context

- Tactics
  - Doctrine
  - Scenario
  - etc.
- (Global Variables)



H + 7



O<sub>2,3</sub> Operator

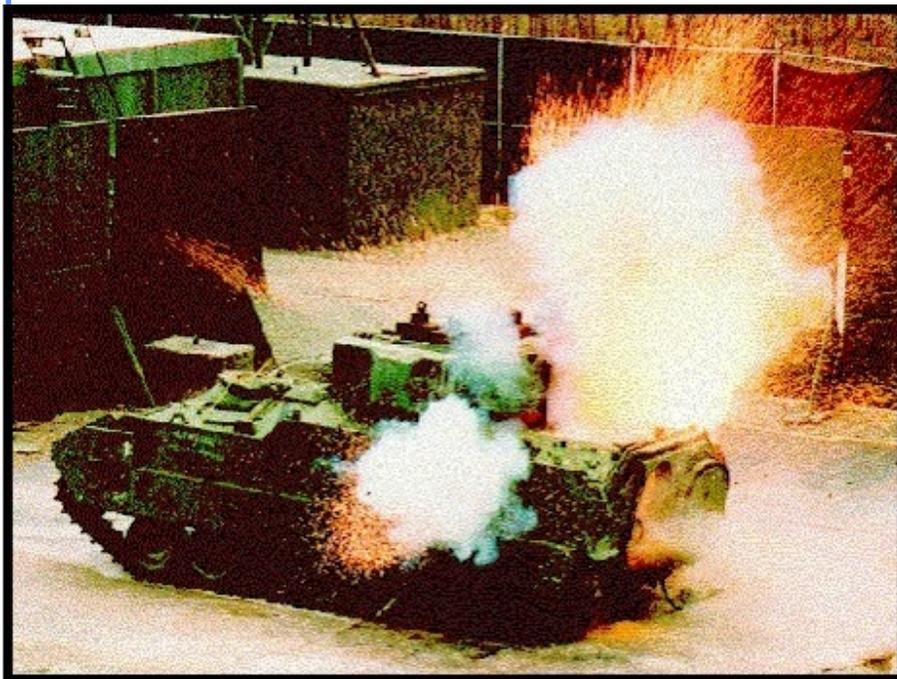
Context Data

Level 2]





# Physical Analogues for the O<sub>1,2</sub> Operator





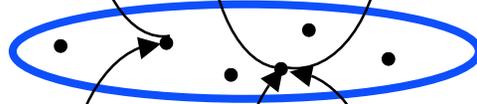
# Abstraction: Platform Live-Fire Test Operator

Level 4]



$O_{3,4}$  Operator

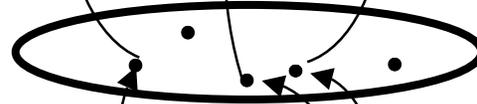
Level 3]



Msn Cap Reqs

$O_{2,3}$  Operator

Level 2]



Context Data

$O_{1,2}$  Operator

Level 1]



Context Data

Risk Factors

Military Operations Context

- Tactics
  - Doctrine
  - Scenario
  - etc.
- (Global Variables)

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# Historical Detour





# Terminal Ballistics → Vulnerability Assessments: Armored Fighting Vehicles

## Importance: V/L considerations influence

- **Data for Decision Makers**
- **Cost & Operational Effectiveness Analyses**
- **Inputs to war games (primary driver in Loss-Exchange Ratios)**
- **Vulnerability Reduction/Lethality Optimization**
- **Spare Parts Requirements for Repair of Battle Damage**
- **Logistics**
- **Weapon/Platform Design/Evaluation Tradeoffs**
- **Personnel Casualties**
- **Training**

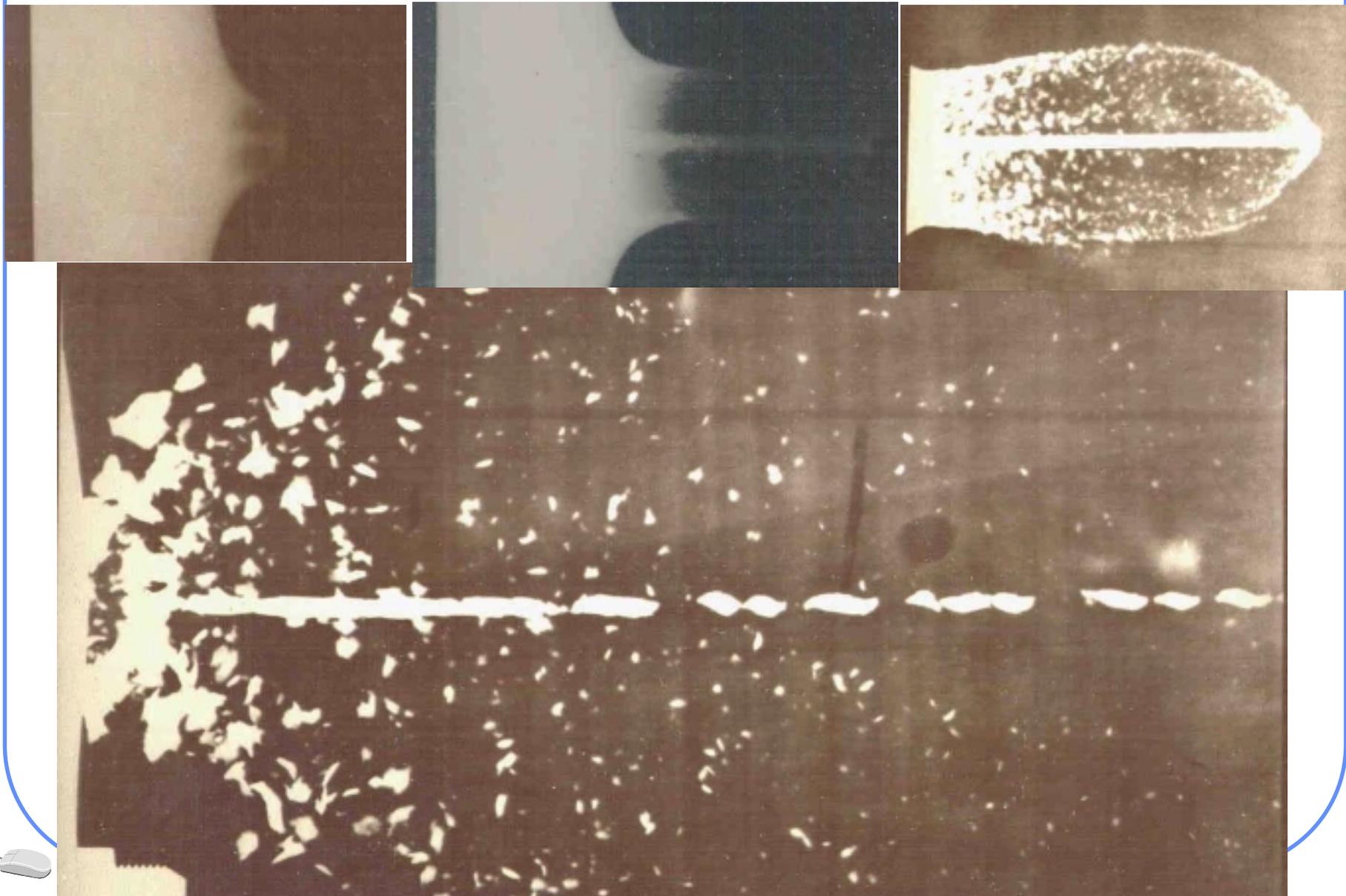


## 1950's Warhead Mechanisms

- **By the mid-50's various antiarmor warhead mechanisms had been developed including:**
  - **Kinetic Energy (KE) Rounds**
  - **Chemical Energy (CE) Munitions**
    - \* **Shaped-Charge (SC) Rounds**
    - \* **Explosively Formed Projectiles (EFPs)**
    - \* **Artillery Fragments**
    - \* **Mines**
- **Specific warhead penetration and overmatch conditions had been evaluated and modeled.**

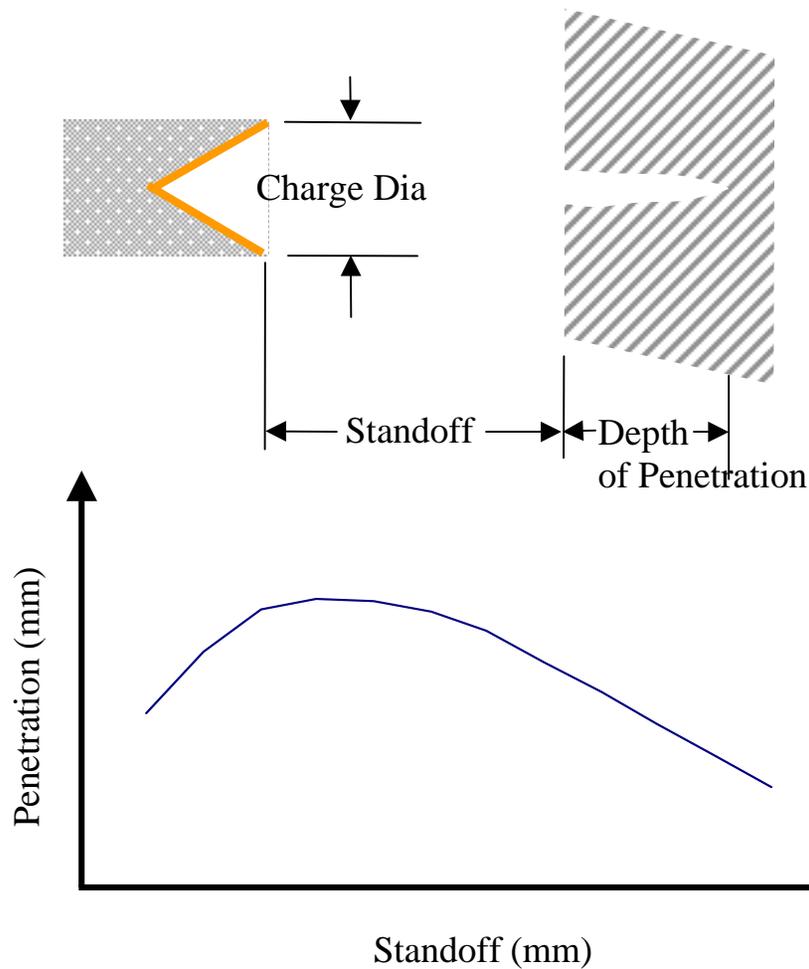


## Shaped-Charge Warhead Overmatch X-Rays





# Shaped-Charge Warheads vs. Rolled Homogeneous Armor (RHA)





## Early Direct-Fire History: 1950s - 1960s

- **1950-1954: SC Tests vs. Vehicles - used to generate  
Compartment Model**
- **1959: 400 SC Shots vs. M47s/M48s**
- **By 1960: ~ 1400 Firings of large munitions vs. heavy  
AFVs**





## Test Observations: 1950s - 1960s

- **Observed penetrator striking point and armor exit hole**
- **Record all damage**
- **Assess catastrophic loss due to fuel or ammo ignition**



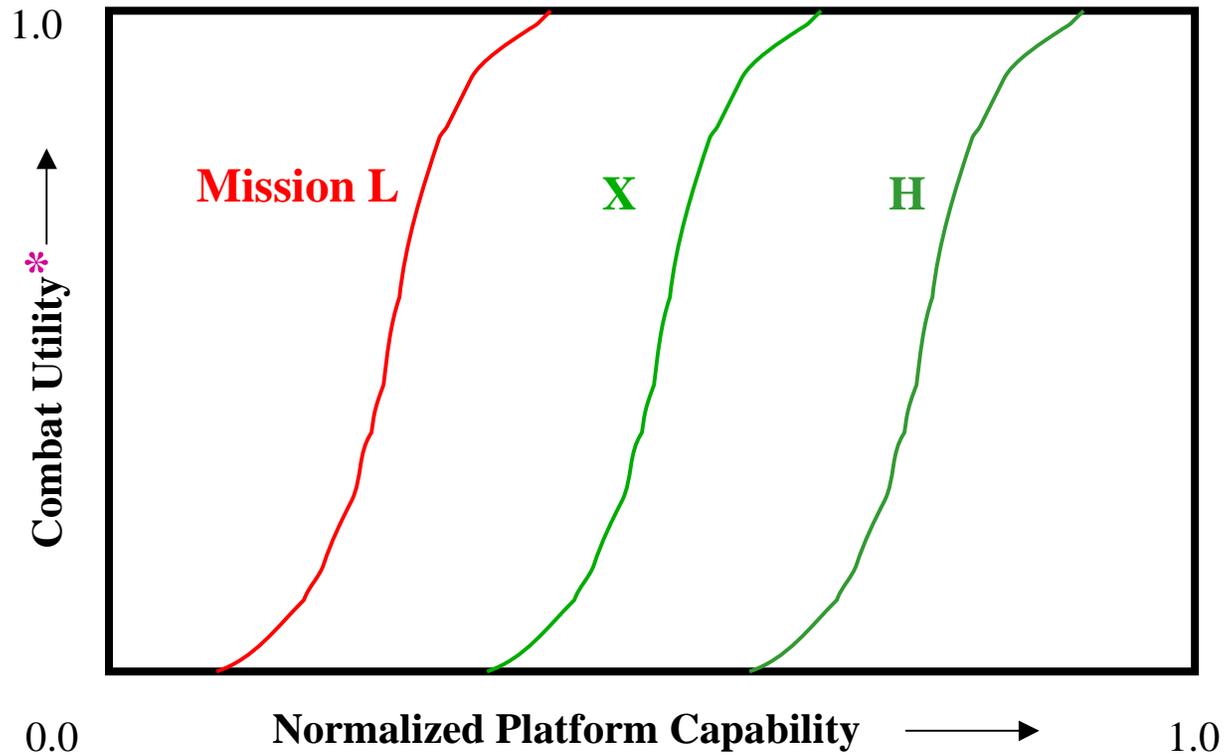


## What was learned: 1950s - 1960s

- **Ballistic interactions cause damage**
- **Damage causes reduction in various capabilities**
- **Reduction in capabilities implies reduction in military value or utility**
- **Extremes:**
  - **No significant damage → Maintain full military utility**
  - **Catastrophic damage → Complete loss of military utility**
- **Problem:**
  - **What about the intermediate case where some damage causes some loss of capability?**
  - **What's the related military utility?**



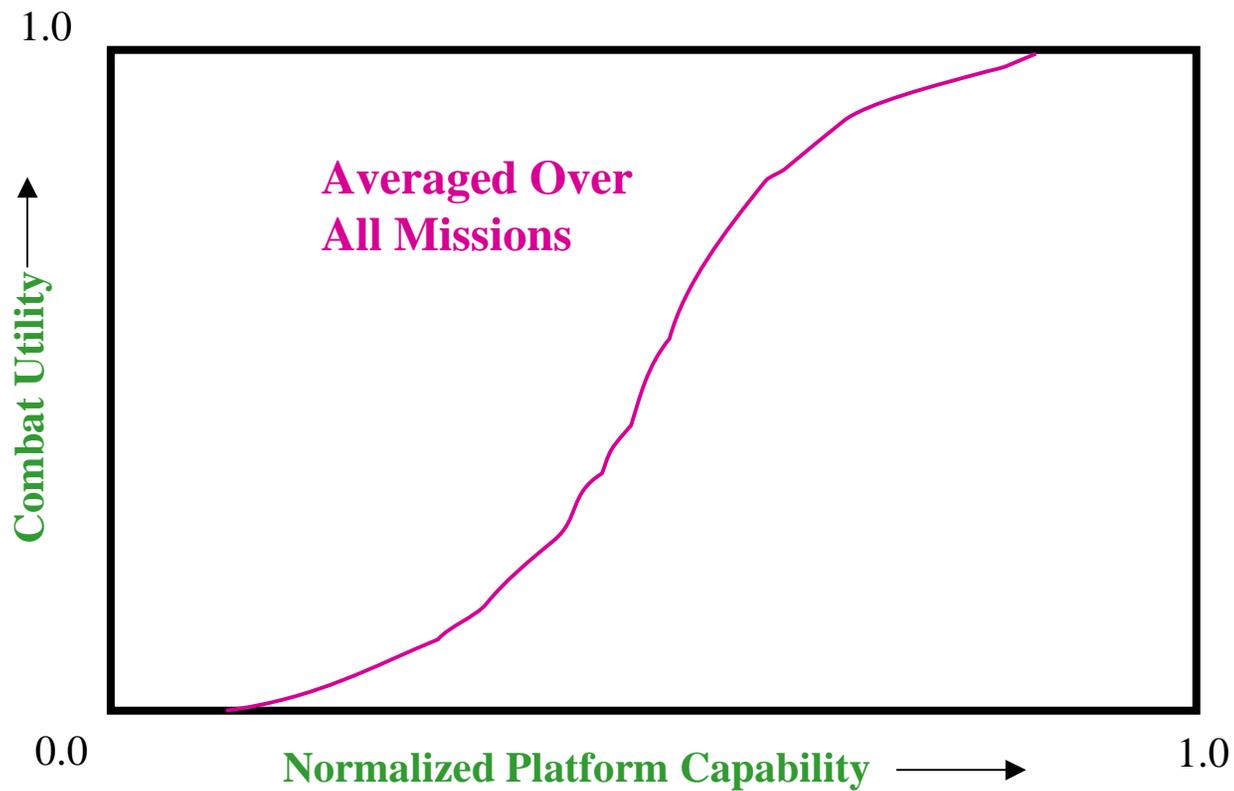
# Notional Combat Utility vs. Capability: circa 1959



\*Fraction of mission(s) successfully prosecuted of given type (L, X, H)



# Notional Expected Combat Utility vs. Capability (Cont)





## Relevant Combat Capabilities?

- **Move (Mobility)**
- **Engage (Firepower)**
- **Communicate**
- **Sense**
- **Replenish**



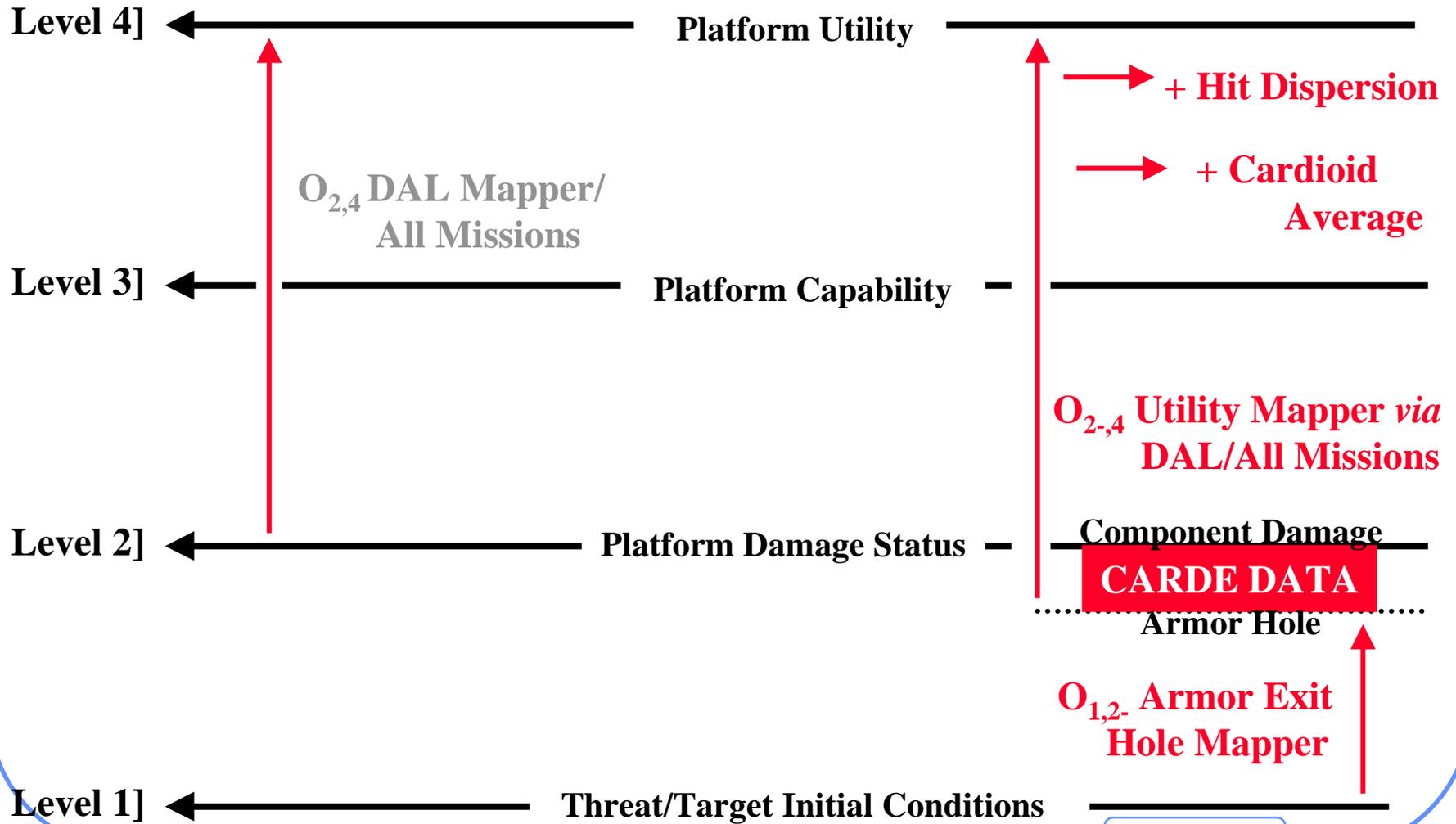


# The Damage Assessment List [DAL]

- **Originally developed in 1959 by Armor Officers and Vulnerability Analysts**
- **Relates loss of Subsystems/Major Components (~250) to Expected Mission Utility (e.g. Mobility, Firepower)**



# Compartment Model Logic

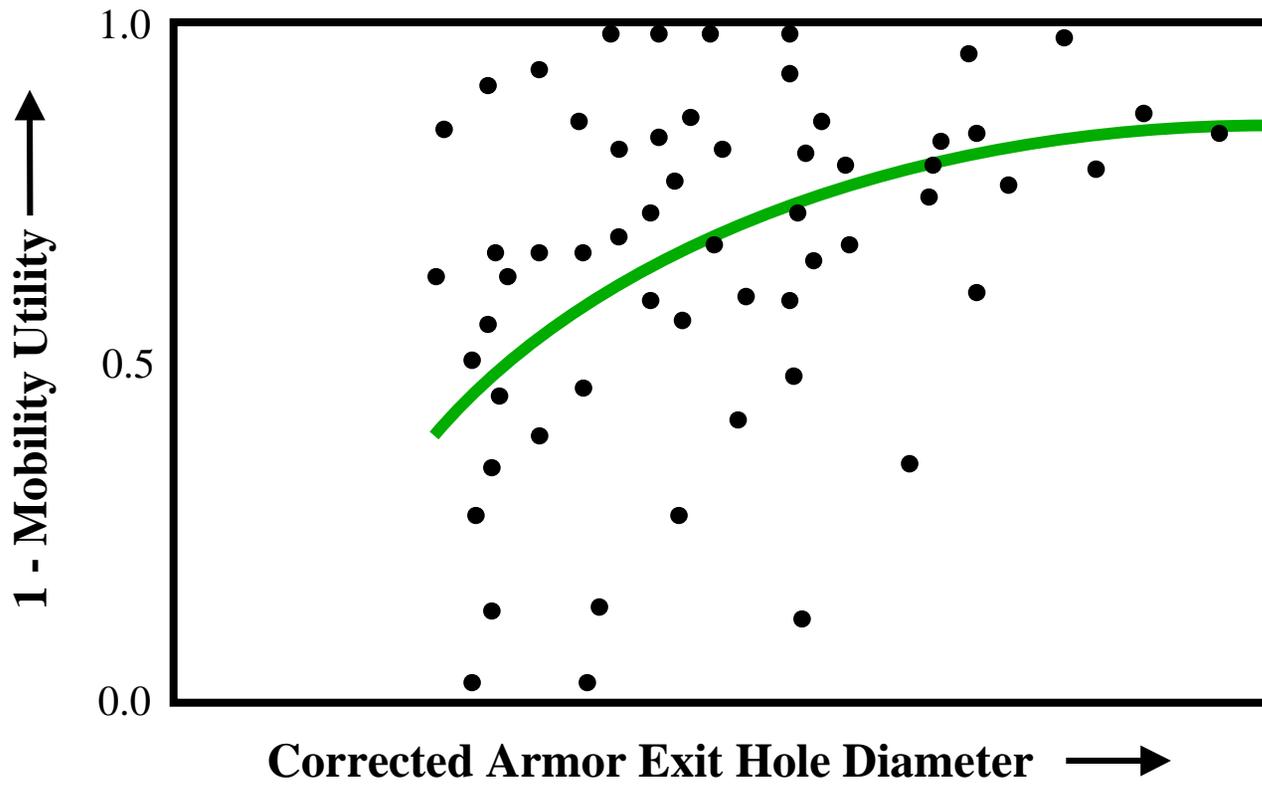


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# [1- Mobility Utility] vs. Armor Exit Hole

Data (circa 1959) from CARDE Tests for a series of Chemical Energy (CE) warheads ranging from 5"- 8"



What are the ramifications of the data scatter?





# Exterior: Compartment-Level Geometry



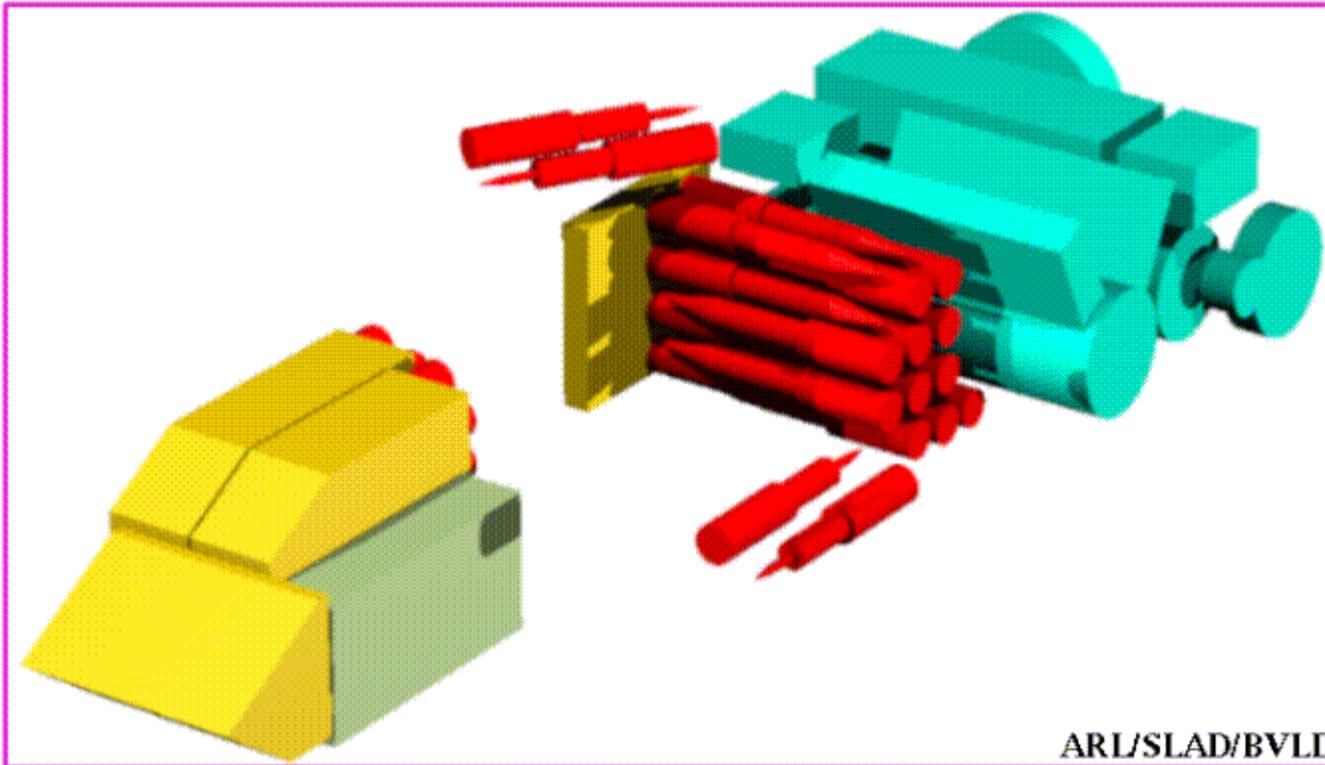
ARL/SLAD/BVLD

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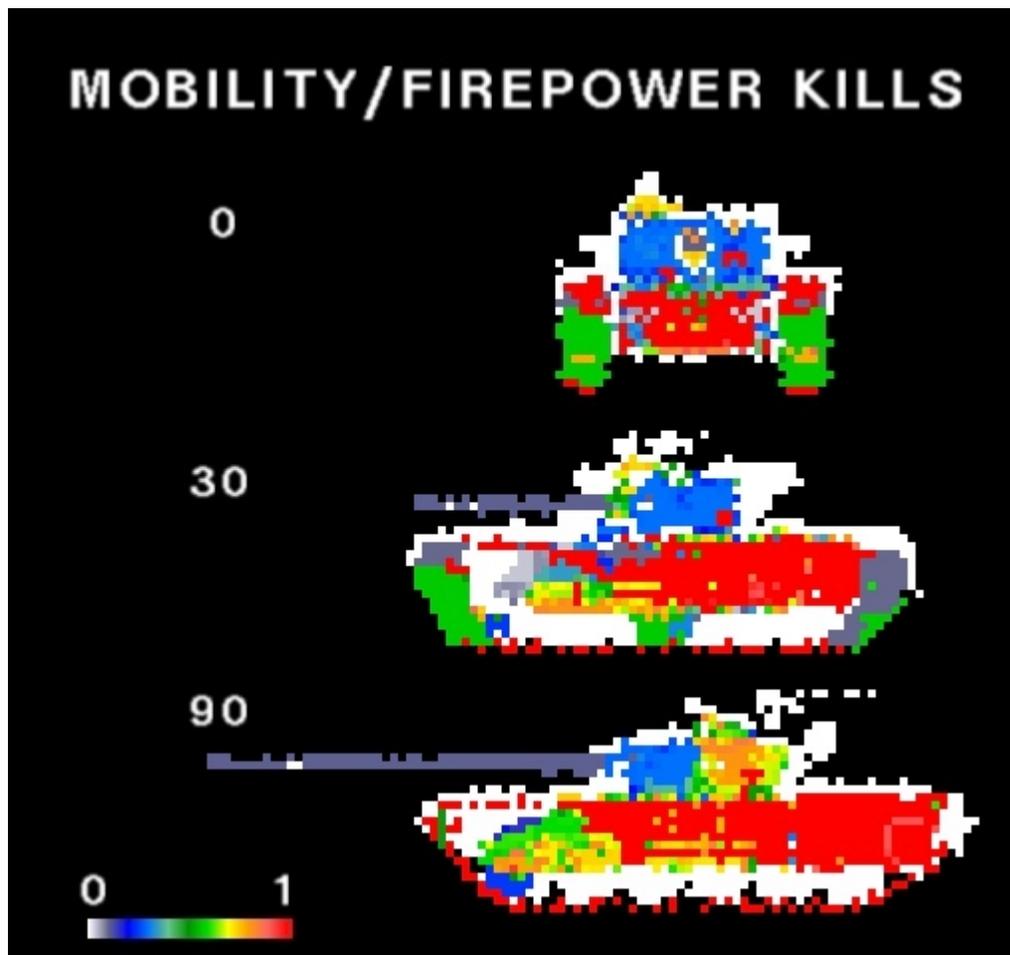


# Interior: Compartment-Level Geometry





# Compartment-Model Color Cell Plot





## Initiation of Live-Fire Testing: 1980s

- **Bradley LF first major program (1984-1985)**
- **Compartment Model judged unacceptable (e.g. no CARDE-type data base for correlation curves)**

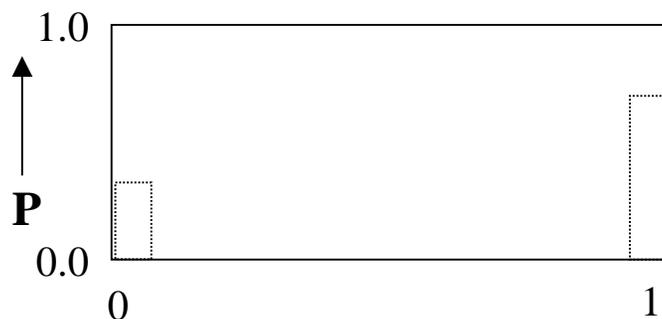




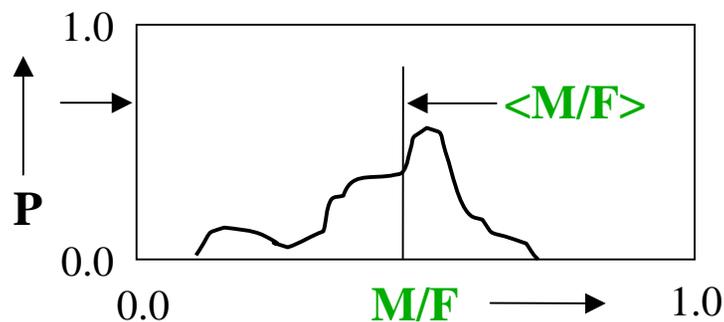
## First Use of AFV Component Methodology (1984)

Point-Burst model called VAST was utilized:

- Plays deterministic spall rings vs. vehicle internal components
- For each encounter, estimates the probability that each component is killed
- Estimates the (Bernoulli) K Kill and the (expected) M and F Utilities



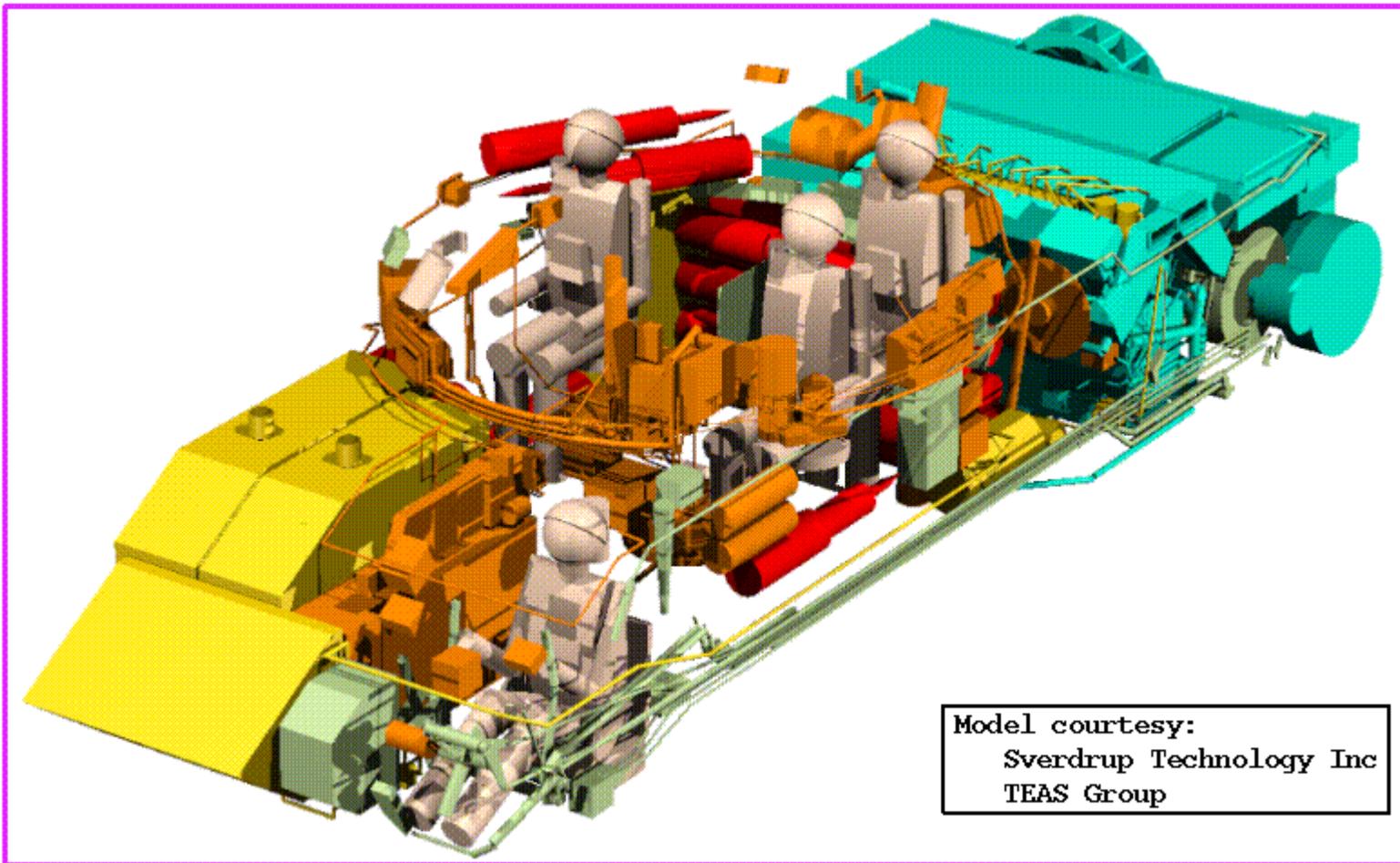
Probability of Catastrophic (K) Kill



Expected values of Mobility (M)  
& Firepower (F) Kills



# Interior: Component-Level Geometry





## A Critic of Vulnerability Modeling

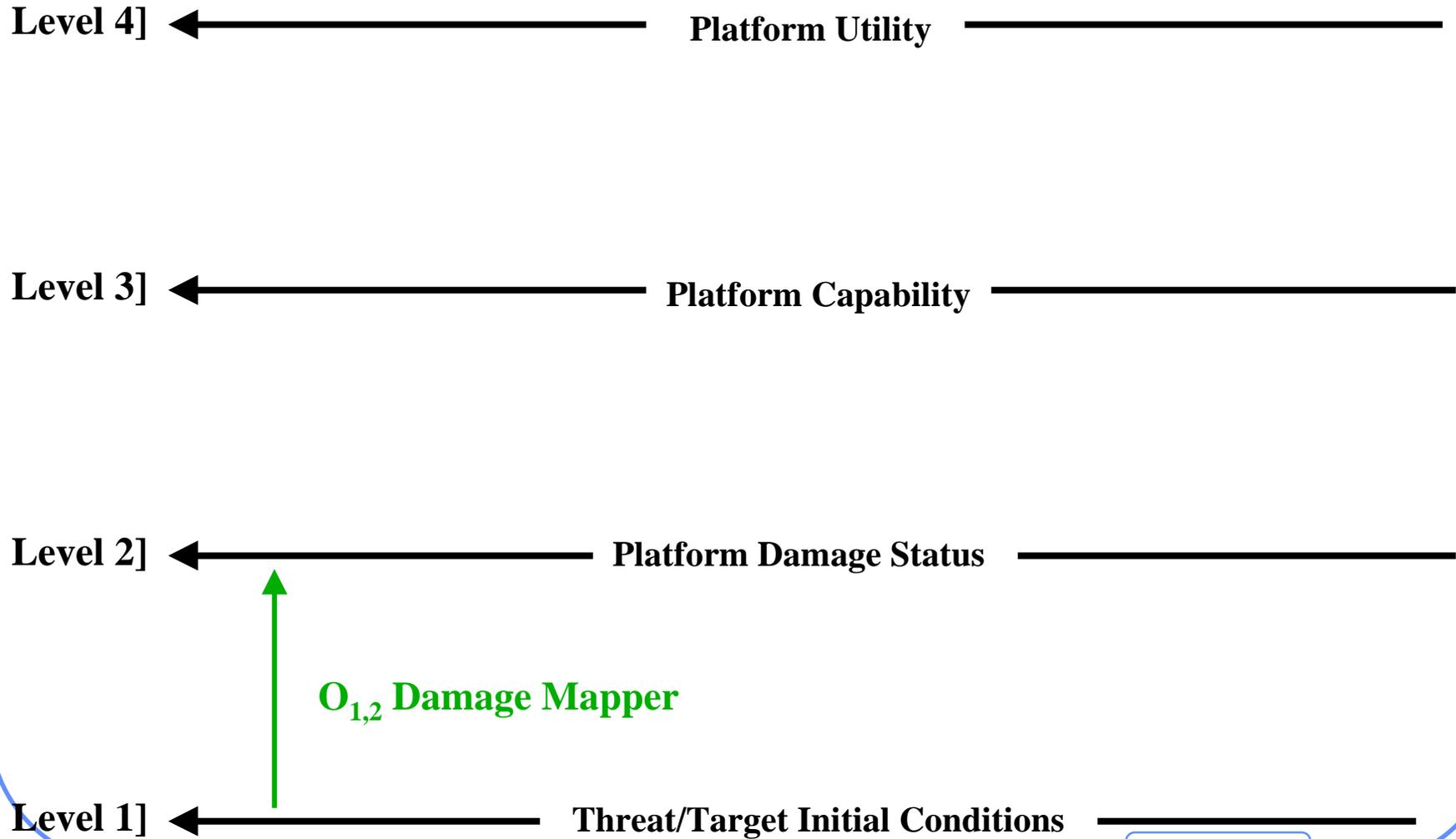
- **LTC Burton** rated the model results according to whether they were within 30% of the corresponding field result
- **“Vulnerability/Lethality Models have no predictive value (surprise?)!”**

**LTC James G. Burton (USAF, Ret), 1985**

**Office of the Under Secretary of Defense for Acquisition**



# SQuASH Live-Fire Modeling: Damage





# Live-Fire Methodology: 1985

Group: **ARMAMENT**  
Damage States, sorted by likelihood

Damage States																													Relative Occurrence	
Component Number																													state	sum
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29		
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	0.275	0.275
☐	☐	☐	☐	☐	☐	•	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	0.078	0.353
☐	☐	☐	☐	☐	☐	•	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	0.077	0.430
☐	☐	☐	☐	☐	☐	•	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	0.060	0.490
☐	☐	☐	☐	☐	☐	•	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	0.039	0.529
☐	☐	☐	☐	☐	☐	•	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	0.026	0.555
☐	☐	☐	☐	☐	☐	•	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	0.023	0.578
☐	☐	☐	☐	☐	☐	•	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	0.013	0.591
☐	☐	☐	☐	☐	☐	•	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	0.011	0.602
☐	☐	☐	☐	☐	☐	•	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	0.010	0.612
☐	☐	☐	☐	☐	☐	•	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	0.010	0.622
☐	☐	☐	☐	☐	☐	•	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	0.010	0.632
☐	☐	☐	☐	☐	☐	•	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	0.009	0.641
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☐	☐	☐	☐	☐	☐	•	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	0.007	0.658
☐	☐	☐	☐	☐	☐	•	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	0.001	0.998
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☐	☐	☐	☐	☐	☐	•	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	0.001	1.000

Converges at the 223rd state

☐ - component undamaged  
• - component damaged

Group: **ARMAMENT**

**SQuASH**

**Killed**

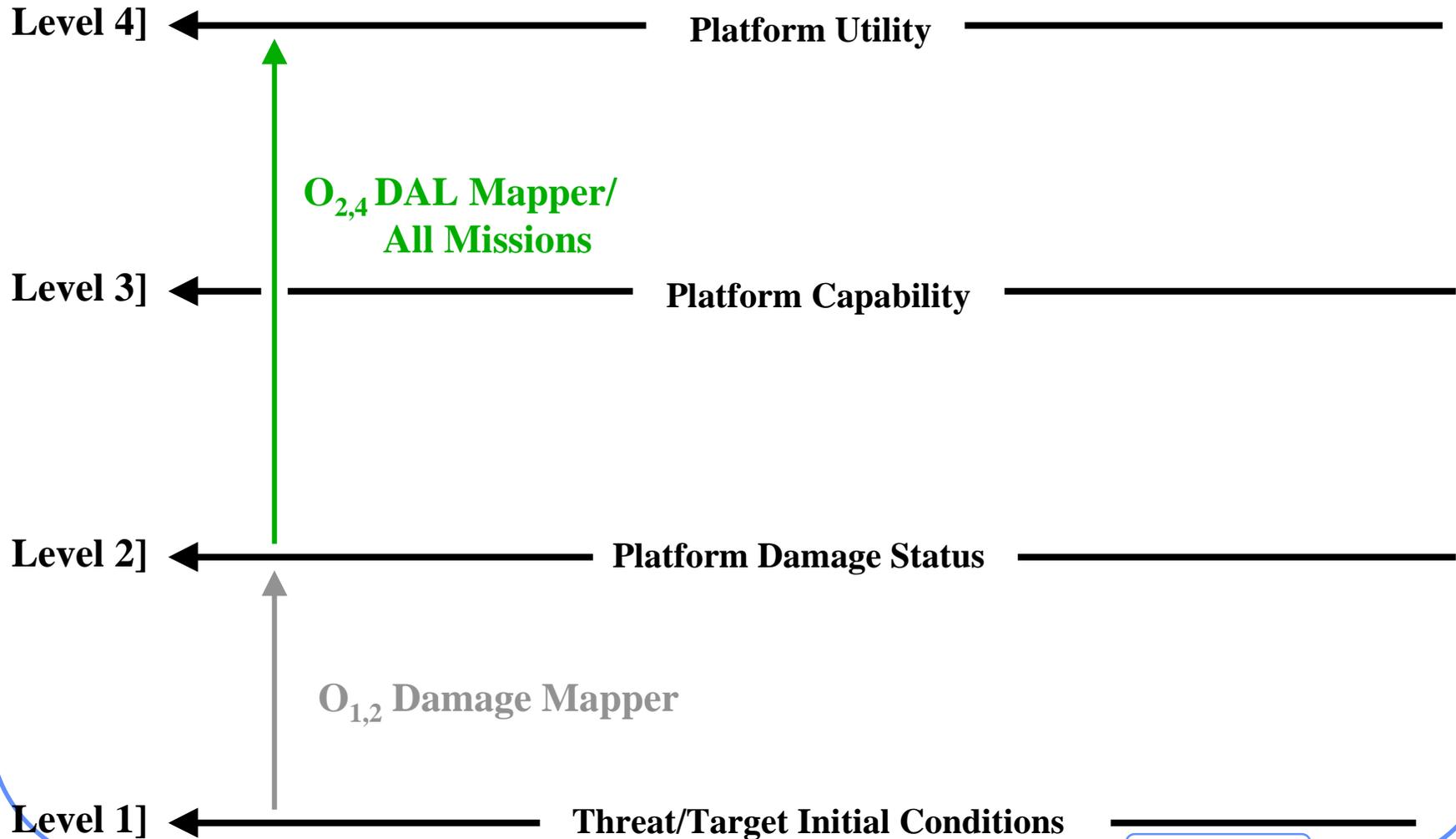
**Components**

Number	Component	Number	Component
1	<i>cable 1w101</i>	16	<i>filter manifold</i>
2	<i>cable 1w101</i>	17	<i>h.lines filter manifold to IIDM</i>
3	<i>cable 1w105-9 main branch</i>	18	<i>h.lines filter manifold to IIDM</i>
4	<i>cable 1w107-9</i>	19	<i>h.lines TDM to azimuth servo</i>
5	<i>cable 1w108-9 to main gun</i>	20	<i>manual azimuth gearbox</i>
6	<i>cable 1w200-9</i>	21	<i>manual elevation pump</i>
7	<i>cable 1w201-9</i>	22	<i>gunner's control handle</i>
8	<i>cable 1w202-9 main branch</i>	23	<i>commander's control handle</i>
9	<i>cable 1w203-9</i>	24	<i>race ring</i>
10	<i>cable 1w208-9</i>	25	<i>h.line check valve to IIDM bypa</i>
11	<i>cable 1w209-9</i>	26	<i>coaxial ready ammo box</i>
12	<i>cable 1w210-9</i>	27	<i>azimuth gearbox - cws</i>
13	<i>gunner's primary sight</i>	28	<i>commander's vision block #2</i>
14	<i>commander's gps extension</i>	29	<i>loader's sight</i>
15	<i>thermal image control unit</i>		





# SQuASH Live-Fire Modeling: Utility



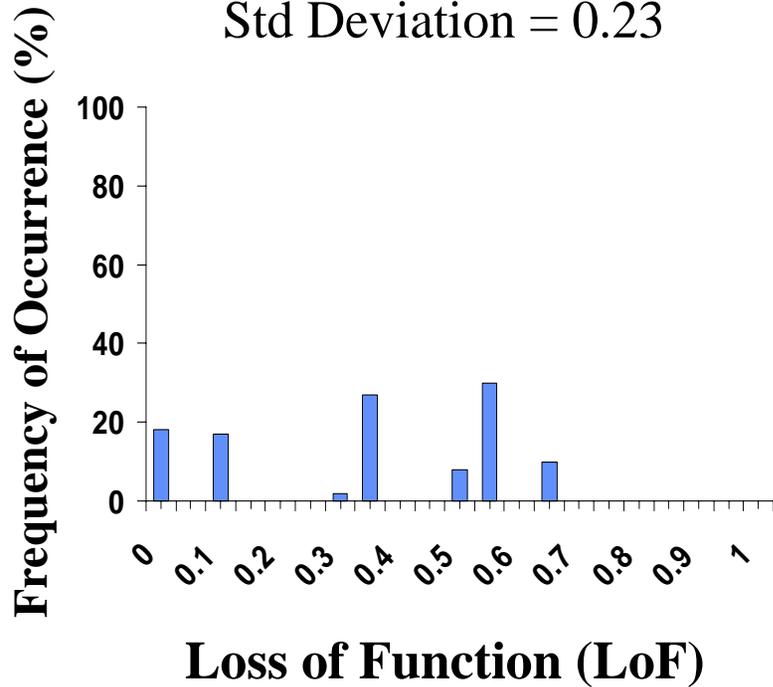


# Live-Fire Methodology: 1985 (Cont)

## SQuASH Utility Distributions

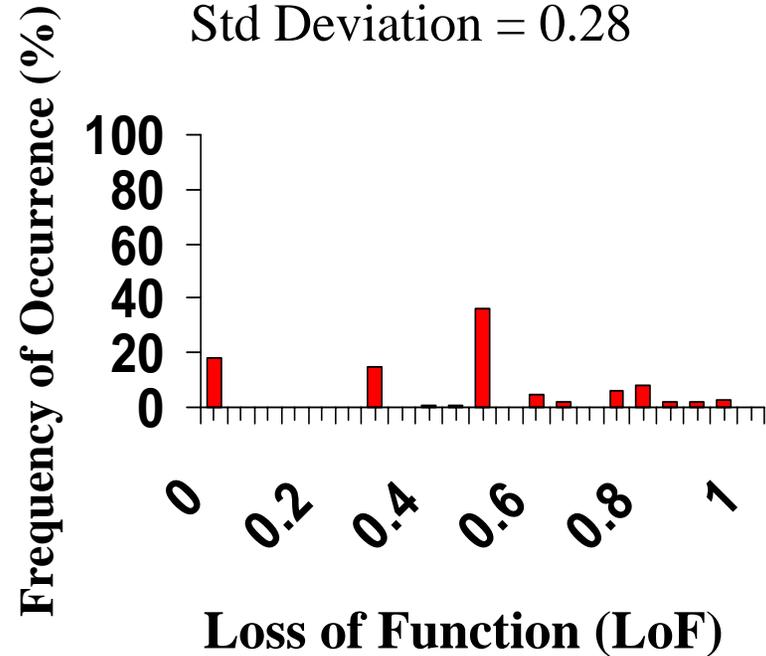
### Mobility Kill

Mean LoF = 0.36  
Std Deviation = 0.23



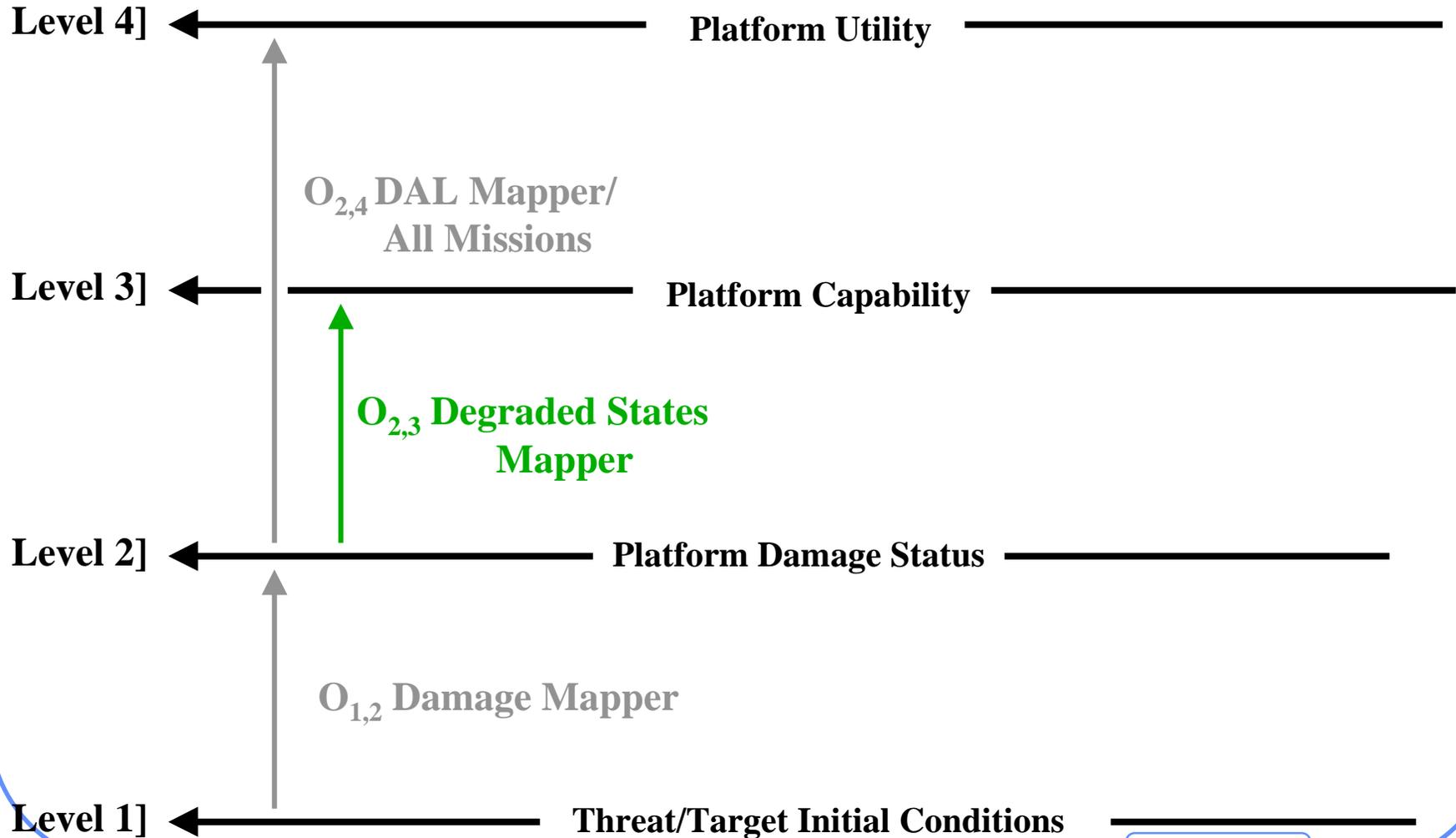
### Firepower Kill

Mean LoF = 0.48  
Std Deviation = 0.28





# SQuASH Live-Fire Modeling: Capability





# Initial Degraded State Metrics: 1988

## MOBILITY

M0 → No mobility damage  
M1 → Reduced speed (slight)

M2 → Reduced speed (significant)  
M3 → Total immobilization

## FIREPOWER

F0 → No firepower damage  
F1 → Loss of main armament  
F2 → Unable to fire on the move  
F3 → Increased time to fire  
F4 → Reduced delivery accuracy  
F5 → Loss of secondary armament  
F6 → F2 and F3  
F7 → F2 and F4  
F8 → F3 and F4  
F9 → F2 and F3 and F4

F10 → F2 and F5  
F11 → F3 and F5  
F12 → F4 and F5  
F13 → F2 and F3 and F4 and F5  
F14 → F2 and F3 and F5  
F15 → F2 and F4 and F5  
F16 → F3 and F4 and F5  
F17 → F1 and F5  
(total loss of fire power)

## ACQUISITION

A0 → No acquisition damage  
A1 → Reduced acquisition capability

A2 → Unable to acquire while moving  
A3 → A1 and A2

## COMMUNICATIONS

X0 → No communication damage  
X1 → No internal communications  
X2 → No external communications  
> 300 ft

X3 → No external communications  
X4 → X1 and X2  
X5 → X1 and X3



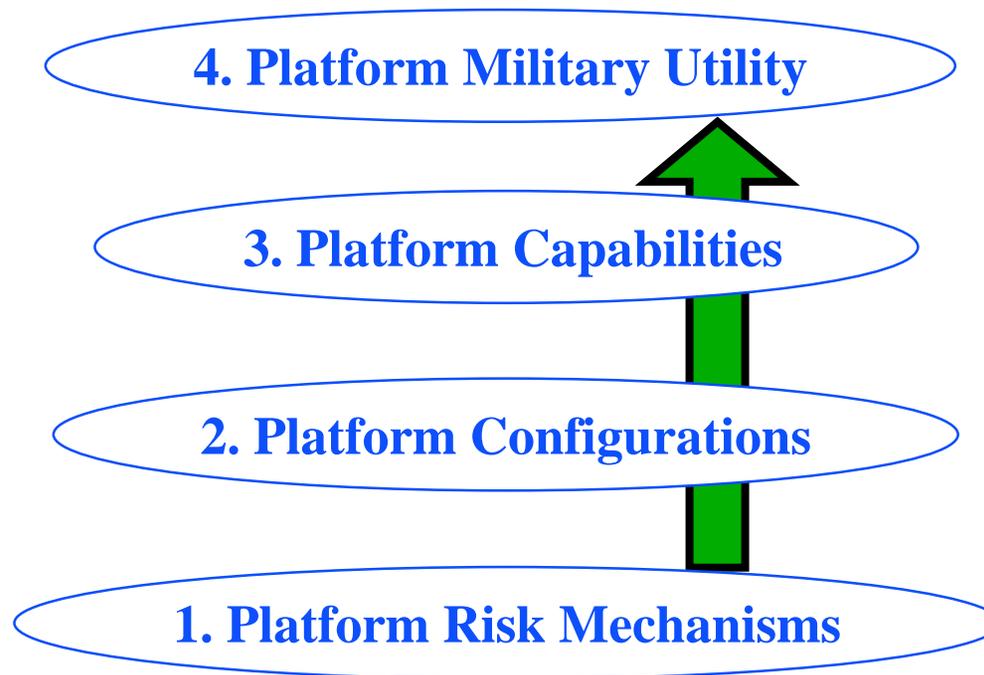
# Back to the Future



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# Using the V/L Taxonomy



## Bottom-Up Analysis Framework

Bottom-up process follows causal (*i.e.*, time-forward) behavior



# Component Change Mechanisms

## **(Quasi-) Perm Damage**

**Ballistic**  
**Chemical**  
**Laser**  
**Directed Energy**  
**High-Pwr Laser**  
**Nuclear**  
**Physics of Failure**  
**Logistics Burdens**  
**(Fuel, Ammo)**  
**Reliability**  
**Fair Wear & Tear**  
**Fatigue<sup>+</sup>**  
**Heat Stress<sup>+</sup>**

## **Temp Damage**

**Electronic Jamming**  
**Cosite Interference**

## **Comp Repair/Fix**

**Battle Damage Repair**  
**Resupply/Replenish**  
**Sleep<sup>+</sup>**

**+ Personnel Related**

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# Level 4] - Mission Outcomes Status



Ablaze, the Arizona slips beneath the water



Measure? Avoidance?



More US Marines won the Medal of Honor on Iwo Jima than in any other battle in US History. In 36 days of fighting there were **25,851 US casualties** (1 in 3 were killed or wounded). Virtually all 22,000 Japanese perished.



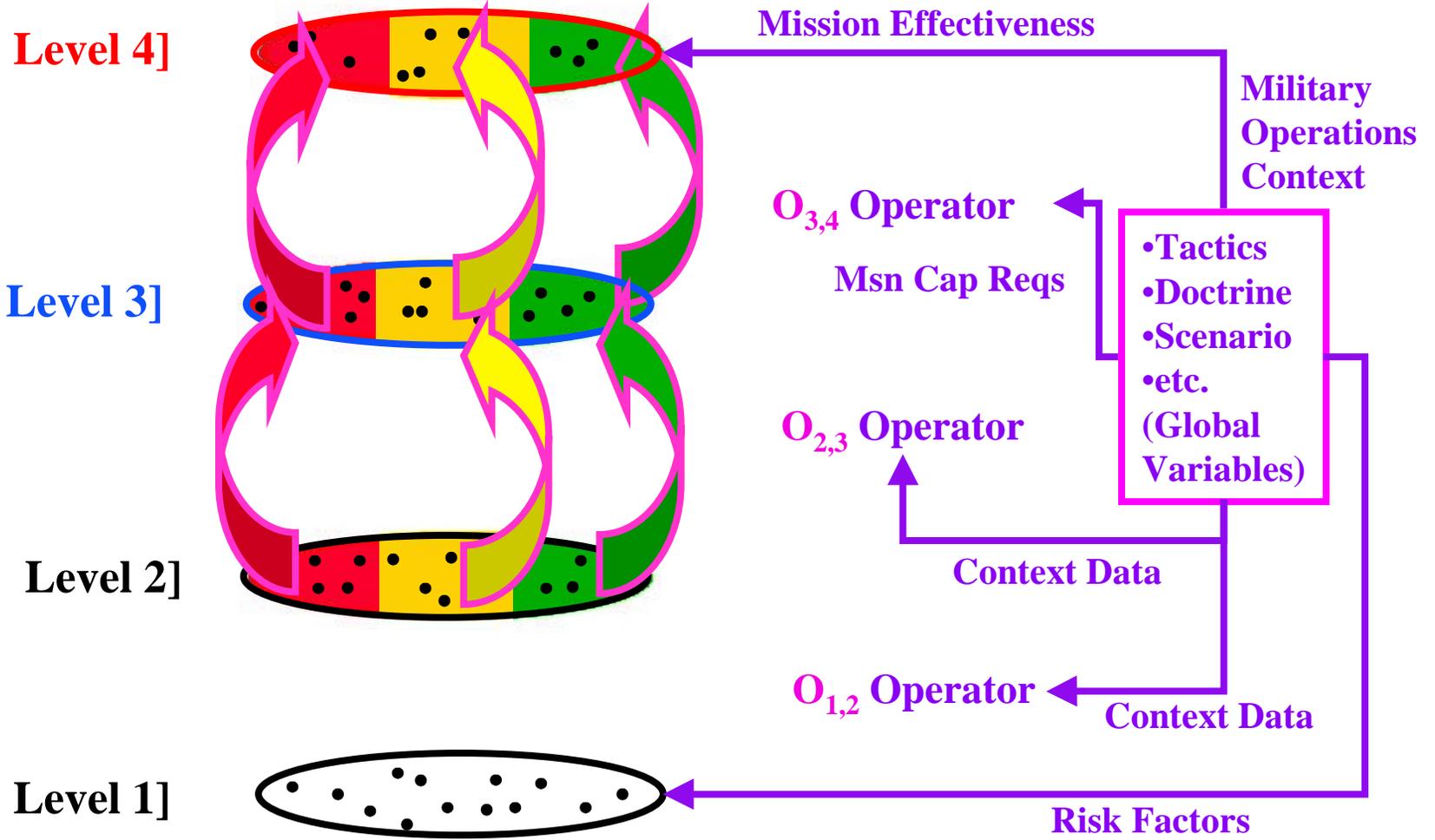
~~Loss Exchange Ratio (LER)~~



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# Mission-Based Utility





# Combined Platform Performance

ACQUIRE



ACQUIRE

ACQUIRE



COMMO



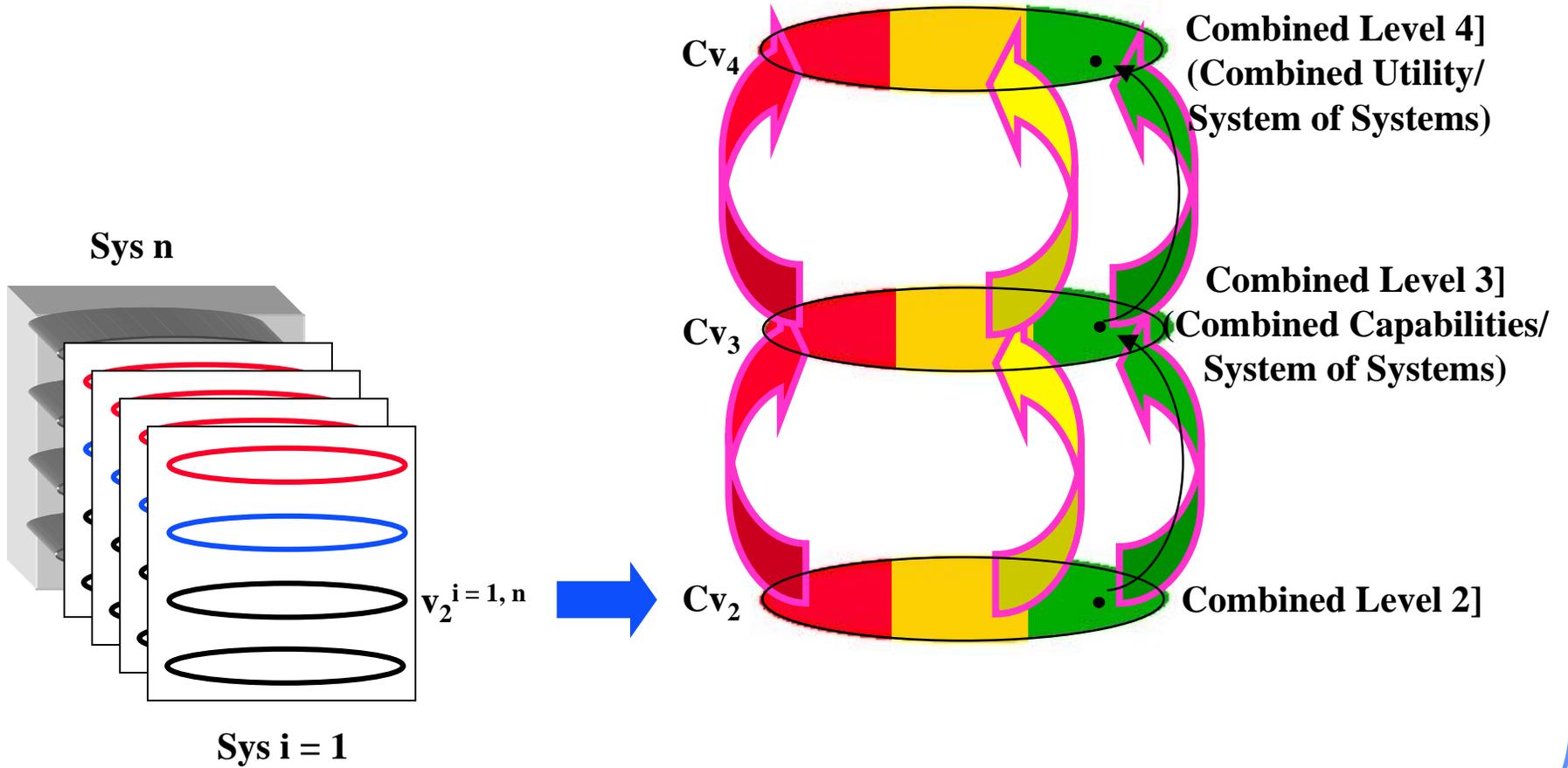
H + 5

ISAA



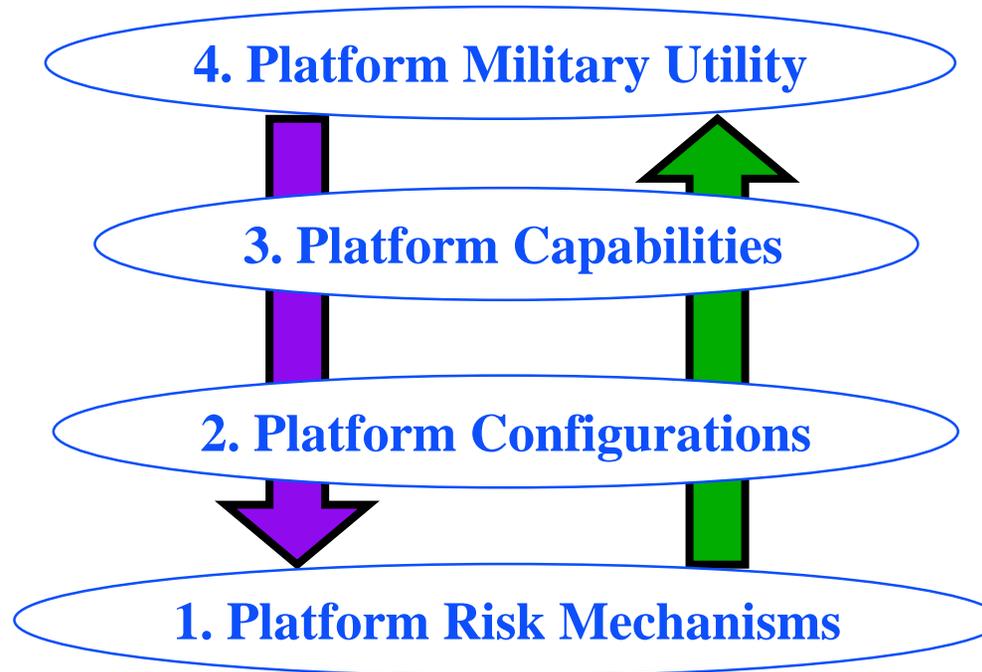


# System-of-Systems





# Top-Down Decompositional Framework

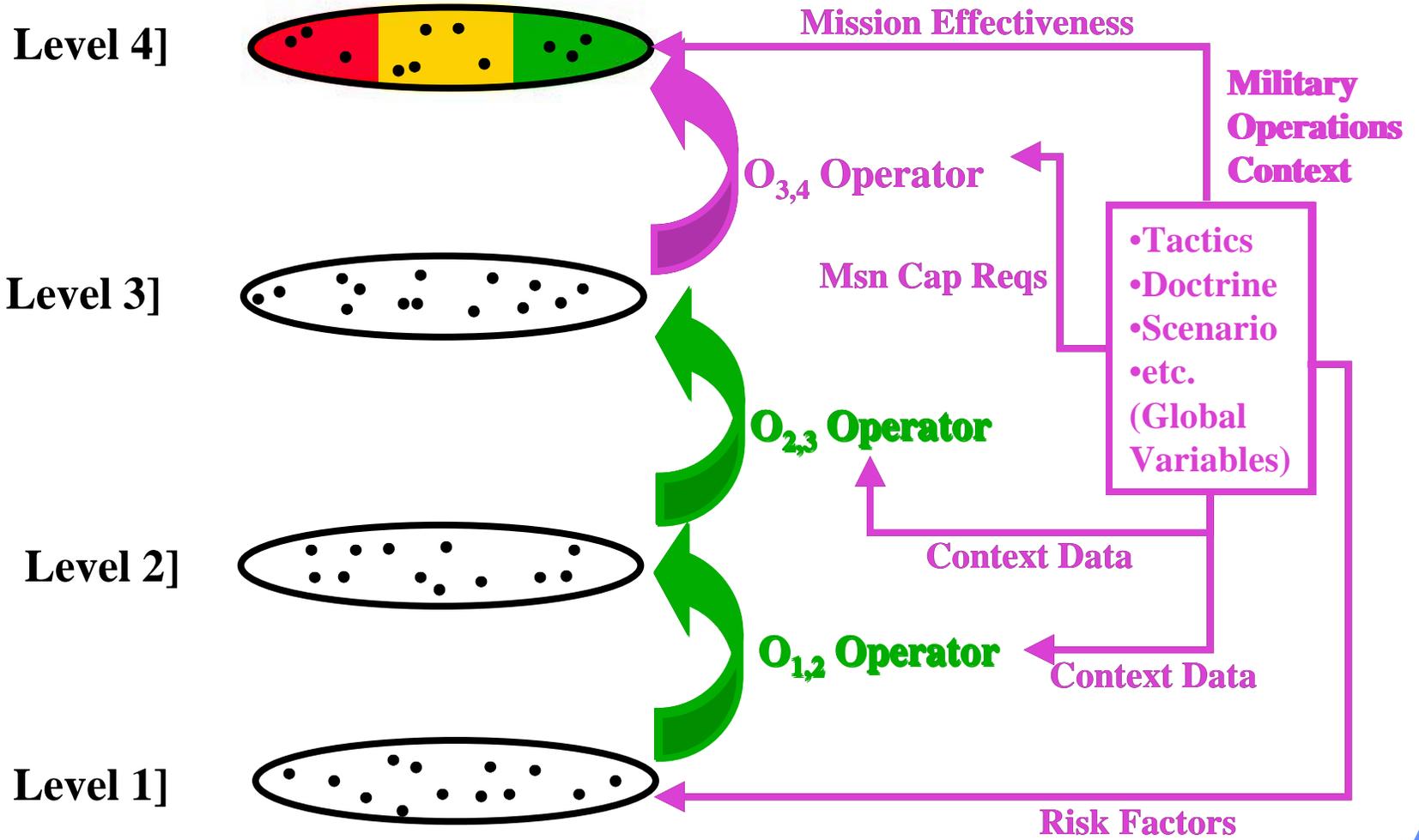


# Bottom-Up Analysis Framework

Bottom-up process follows causal (*i.e.*, time-forward) behavior



# Division of Labor: **Scientist/Engineer** *and* **Warfighter/Operator**





## Summary

- **Have described an analysis framework that:**
  - has three linked metrics – utility, capability, componentry
  - where utility is based on mission-related capabilities
  - capabilities are based on componentry
  - platform componentry is the fundamental metric, and
  - the linkages include dependencies on specific military mission/context
- **Platform effectiveness can change with time as:**
  - a] mission requirements change, and/or
  - b] the component infrastructure degrades or is reconstituted
- **As a mission proceeds in time, the levels are mapped from the bottom up**



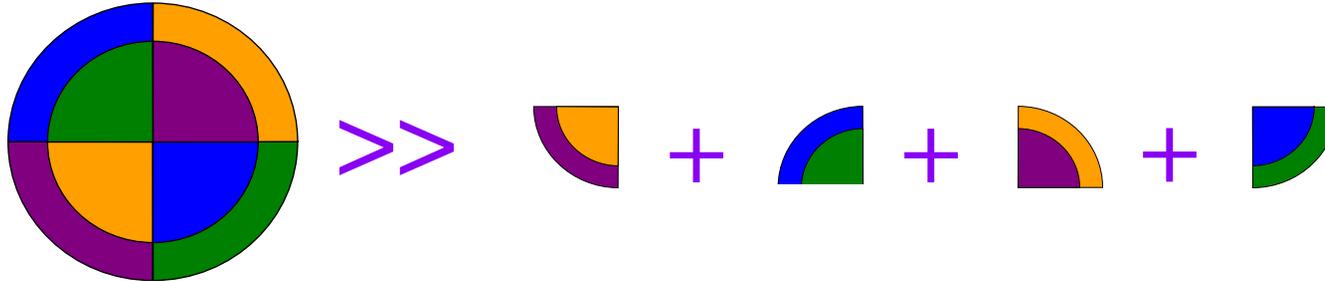
## Summary (cont)

- **However, to develop an effective platform design, the process must be reversed so as to begin with the desired mission outcome, then infer the relevant capabilities, etc.**
- **To develop a system-of-systems, an inverse inferencing process must begin with a concept of combined platform utility, then combined platform capabilities, then combined platform component linkages, etc.**
- **Process implies a clear division of labor between the Scientist/Engineer and the Warfighter/Operator**

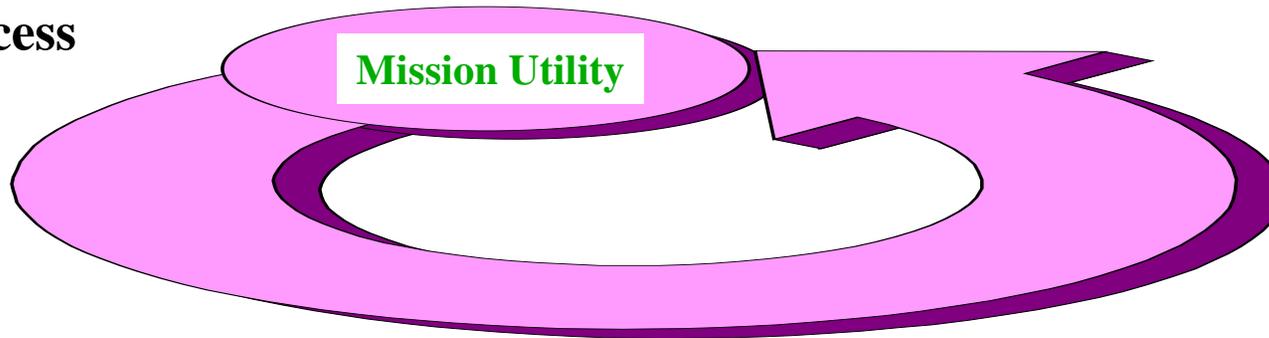


# Conclusions

- With an instantiated environment -



- Process



- Mission Utility  Platform Technology
- Applicable to “Systems-of-Systems” *e.g.* Communication Systems
- Provides structure for C/B, CAIV, and AoA analyses





## References

- P. H. Deitz, *A V/L Taxonomy for Analyzing Ballistic Live-Fire Events*, **Proceedings of the 46<sup>th</sup> Annual Bomb & Warhead Technical Symposium**, 13-15 May 1996, Monterey, CA; also US Army Research Laboratory Technical Report ARL-TR-1274, December 1996.
- P. H. Deitz and M. W. Starks, *The Generation, Use, and Misuse of 'PKs' in Vulnerability/Lethality Analyses*, **The Journal of Military Operations Research**, Vol. 4, No. 1, 1999.
- F. Haddix, *The Conceptual Models of the Mission Space (CMMS) Data Representation and Interchange Specification*, **Proceedings of the 1999 Fall Simulation Interoperability Workshop**, sponsored by the Simulation Interoperability Standards Organization, September 1999.
- R. Luman, *Upgrading Complex Systems of Systems: A CAIV Methodology for Warfare Area Requirements Allocation*, **66<sup>th</sup> Military Operations Research Society Symposium**, Working Group 26, 24 June 1998.
- E. L. DuBois, W. P. Hughes, and L.J. Low, *A Concise Theory of Combat*, **Institute for Joint Warfare Analysis**, Naval Postgraduate School, 1999.
- P. H. Deitz, *Parsing SMART: What Are the Pieces and How Do They Fit Together?*, **Proceedings of the 1999 Fall Simulation Interoperability Workshop**, sponsored by the Simulation Interoperability Standards Organization, September 1999.



# Platform Analysis Perspective

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**Presented at The Defense Modeling and Simulation Office (DMSO) Industry Days, held at the Sheraton Premiere at Tyson's Corner, Vienna, VA, 22-24 May, 2000.**

**AMSAA**



# Backups



## Structuring Level 2]

Increasing Detail

Total Platform

Systems

Subsystems

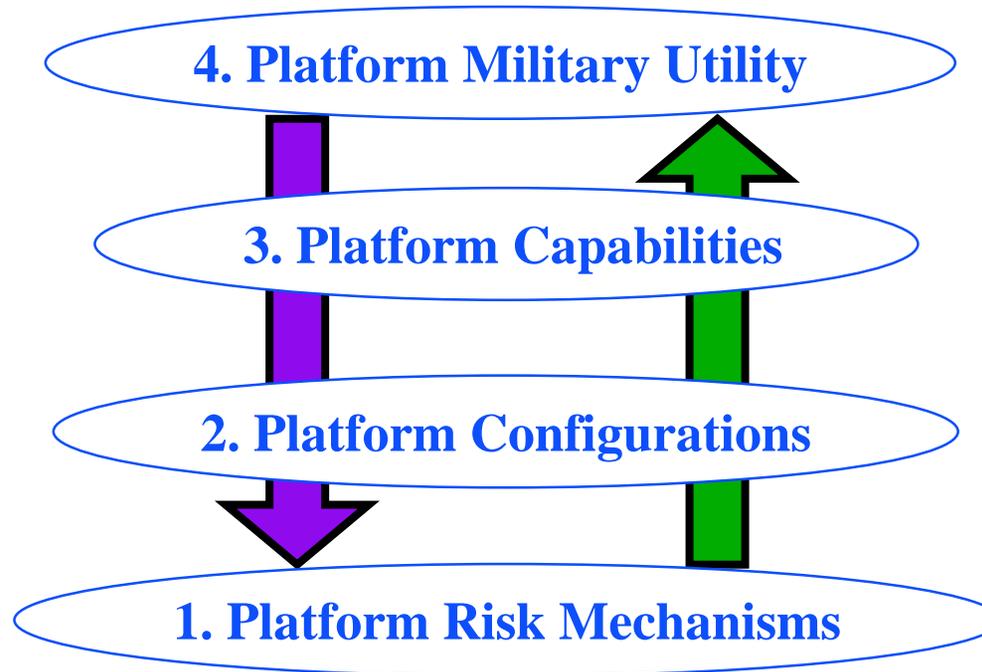
Assemblies

Individual Parts

Increasing Aggregation



# Top-Down Decompositional Framework



# Bottom-Up Analysis Framework

Bottom-up process follows causal (*i.e.*, time-forward) behavior



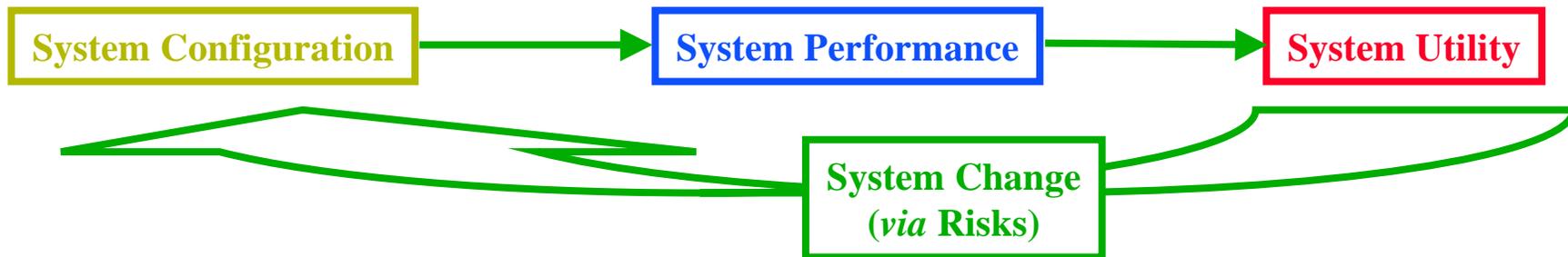
## Audience Survey?

- **How many attendees are from the damage or repair community?**
- **How many are from the single-platform performance community?**
- **How many are from the multi-platform performance community?**
- **How many are from the military effectiveness community?**
- **How many are familiar with at least two of the areas?**
- **How many are familiar with at least three of the areas?**



## Summary (cont)

- **Framework shows:**
  - Pieces/Metrics
  - Connections/Operators
  - Linkage to real military operations/context
  - Damage operator generalized to many risk events
  - Process cycled through time-steps/events
  - Importance of global variables
  - Avoidance of early averaging
- **Typifies many Operations Research analyses:**



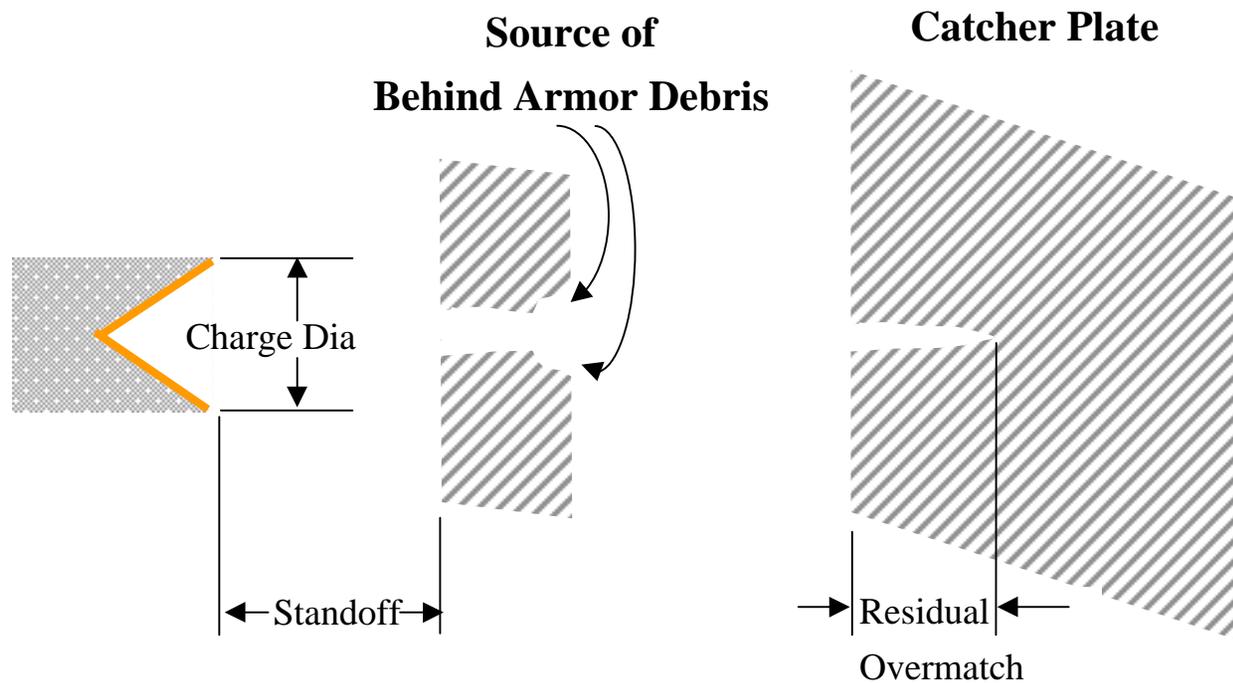


## Summary (cont)

- **Risk Mechanisms:**
  - Driven by both external (MOC) as well as intrinsic (platform configuration) factors
  - Many inputs shared, many processes similar
  - All outputs (*i.e.*, Level 2]) share same vector descriptor
- Single integrated mapper for micro-platform status to macro-platform capabilities
- Mission Effectiveness (Level 4]) is evaluated in terms of (eroding) capabilities vice mission requirements
- To maintain flexibility and extensibility of the process, must keep the levels and operators separate (eschew early averaging!)

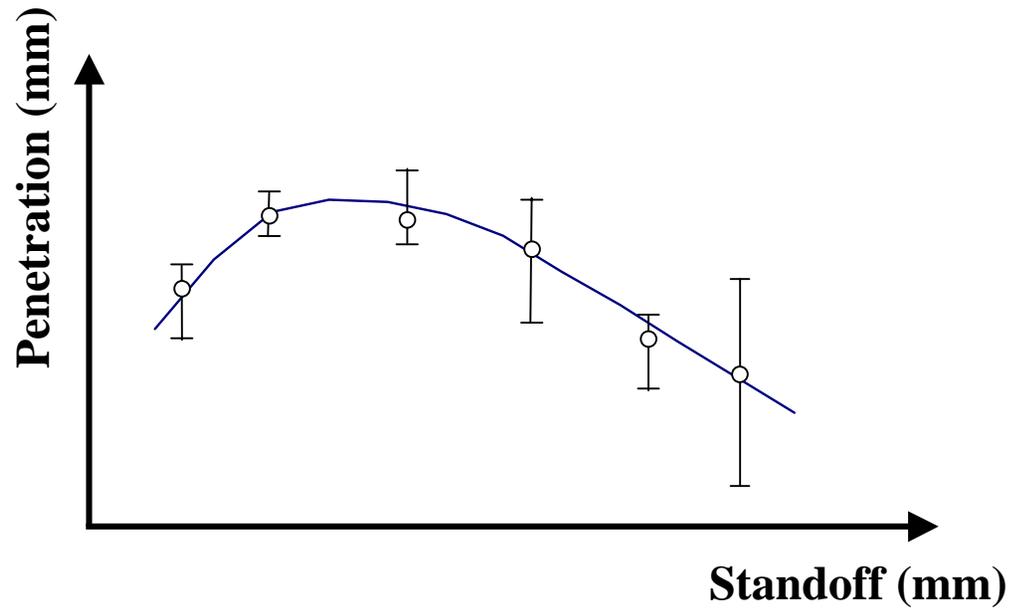


# Shaped-Charge Warheads vs. Rolled Homogeneous Armor (RHA) (Cont)





# Shaped-Charge Penetration Standoff Curve



What are the ramifications of the error bars?

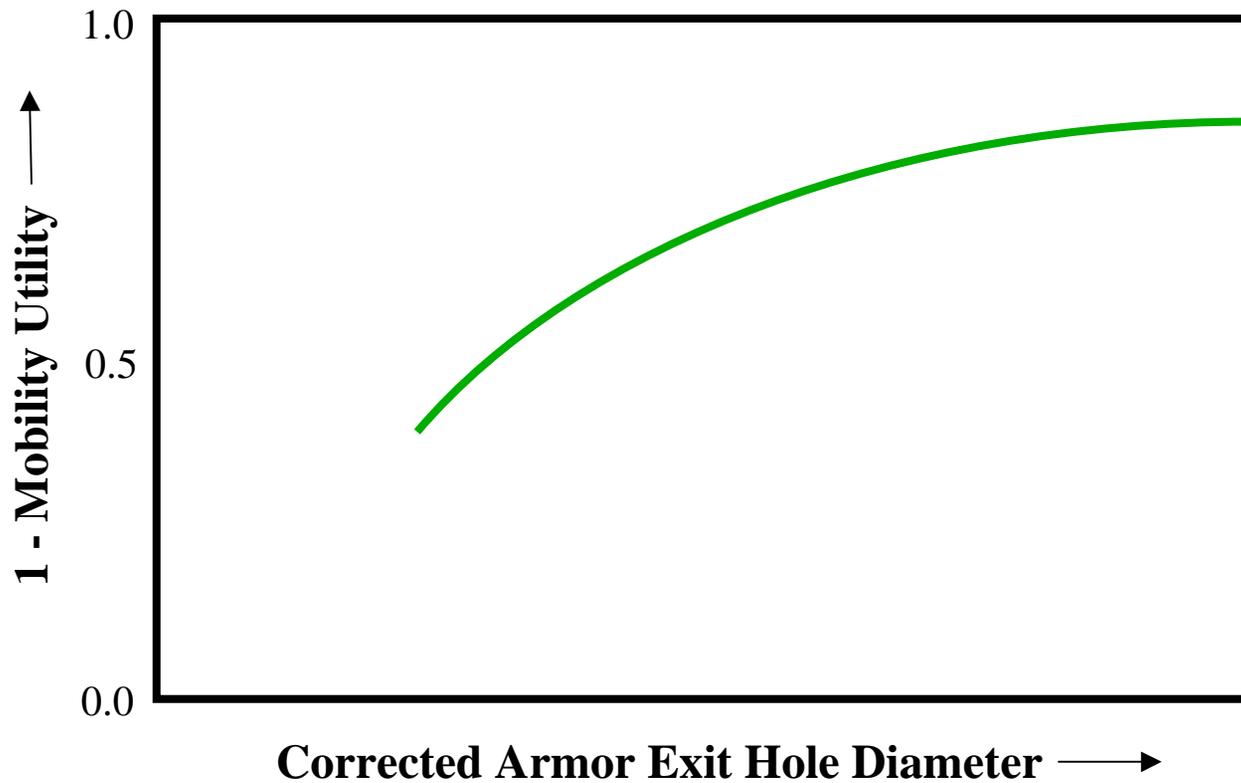


# Compartment Model Methodology

- **Assumption: Target damage  $\propto$  armor exit hole**
- **Compartment Model Logic:**
  - Exterior Suspension Damage?
  - Exit Hole in Armor
  - Residual hit fuel/ammo
  - Map Exit Hole (through explicit damage, through explicit capability) to expected mission utility



# [1 - Mobility Utility] vs. Armor Exit Hole



Curve (circa 1959) from CARDE Tests for a series of Chemical Energy (CE) warheads ranging from 5"- 8".



# AFV Analysis: 1950s-1960s

## Observations

- **Ballistic Interactions → Physical Damage →  
Loss of Capability → Loss of Utility**
- **Physical Damage and Loss of Capability can be measured;  
Loss of Utility can only be inferred**
- **SDAL formalized relationship between loss of tank subsystems/major components and average battlefield utility**
- **Compartment Model codified a relationship between armor exit hole and expected mission utility (over all missions, terrain, weather, diurnal cycles, etc.)**

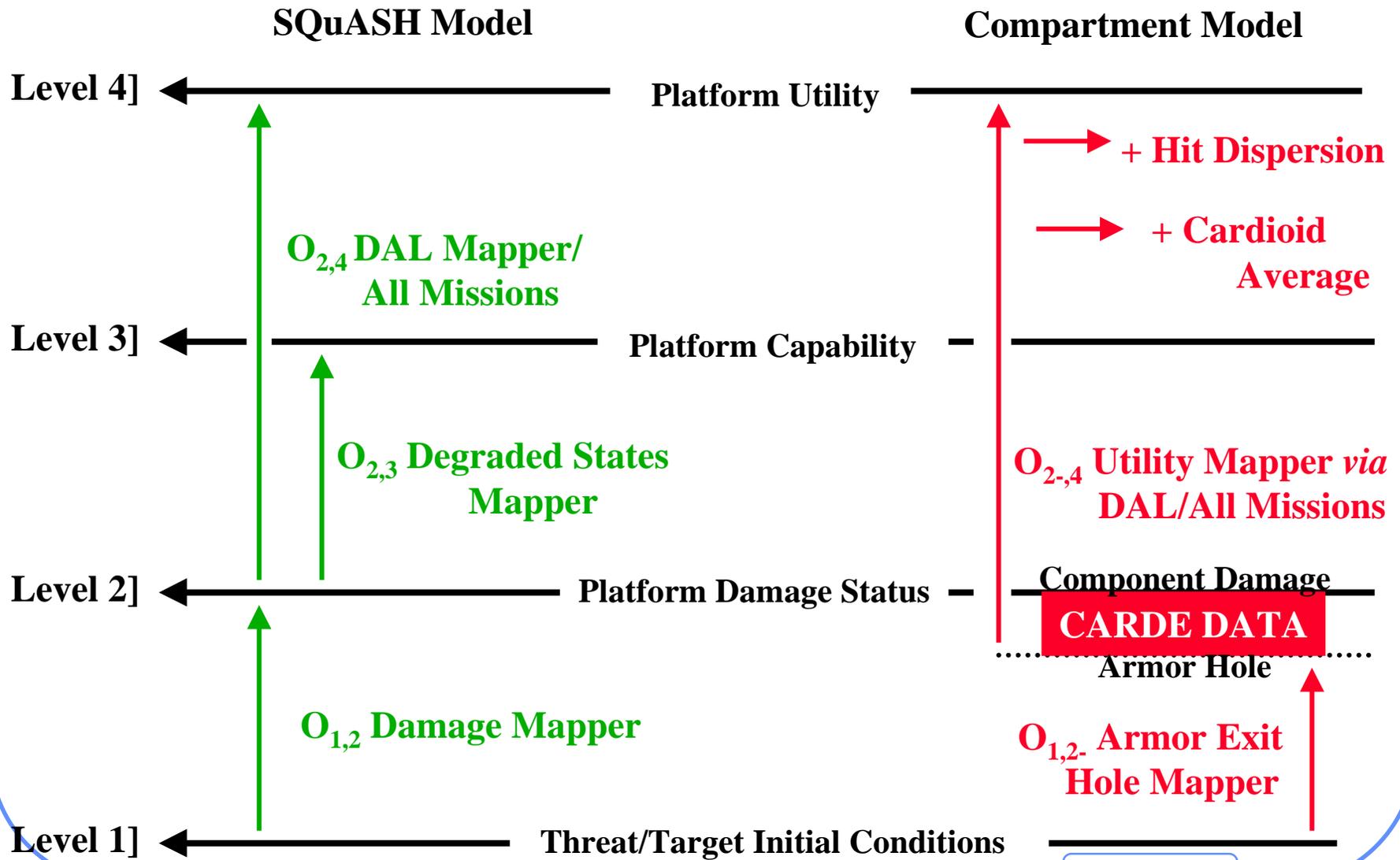


## AFV Analyses: 1950s-1960s (Cont)

- **Average battlefield utility was (*de facto*) defined as equivalent to Probability of Mission Kill; hence familiar terms of Mobility and Firepower “PKs”; hence use of PKs in war games as capability metrics used to estimate mission utility metrics such as loss-exchange ratios**
- **For each warhead hit point *vs.* a target, there is a (single) “PK”**



# Testing/Modeling Activities





## The Interdiction Kill Issue: 1989

- **Evaluation of damage beyond the FEBA for logistical and tactical targets.**
- **Prior DAL mappings not relevant**
- **Joint BRL/AMSAA team developed a mapping called Degraded States (DS). Killed components are mapped to measurable performance metrics using fault trees.**

