Nuclear Survivability Overview

Presented to Chemical, Biological, Radiological and Nuclear Survivability Conference

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Survivability addressed in 2010 Nuclear Posture Review (NPR) and Quadrennial Defense Review (QDR)

- NPR addresses a survivable U.S. response force
  - Continue Minuteman III Life Extension Program to keep the fleet in service to 2030
  - Retain dual-capable bombers with over $1B over next 5 years to support survivability and improve mission effectiveness of the B-2
  - Make new investments in NC2 system to maximize Presidential decision time in a nuclear crisis

- QDR initiative include
  - Strengthen key supporting capabilities for strategic communications
  - Improve survivability of space systems and infrastructure

OSD has elevated nuclear survivability with a permanent Defense Science Board (DSB)

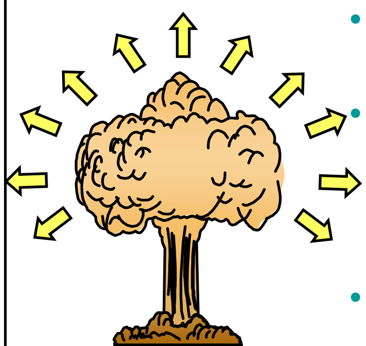
- Permanent DSB task force to assess all aspects of the survivability of DoD systems and assets to EMP and other nuclear weapons effects
  - Build on the work of the EMP Commission and related DSB efforts
    - "The Nuclear Weapons Effects National Enterprise," May 10
    - "Nuclear Weapon Effects Test, Evaluation, & Simulation," Apr 05

- Task Force to assess the implementation of DoDI 3150.09, CBRN Survivability Policy, and the effectiveness of the management oversight group established by the DoDI
  - Conduct an independent review and assessment of DoD's EMP survivability program and review other matters associated with nuclear survivability

Radiation Output of Nuclear Weapons

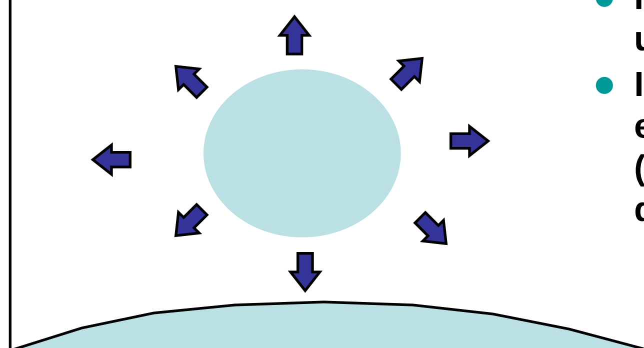
The environments of the nuclear weapon are driven by the highly energetic products of underlying nuclear reactions

Near Surface

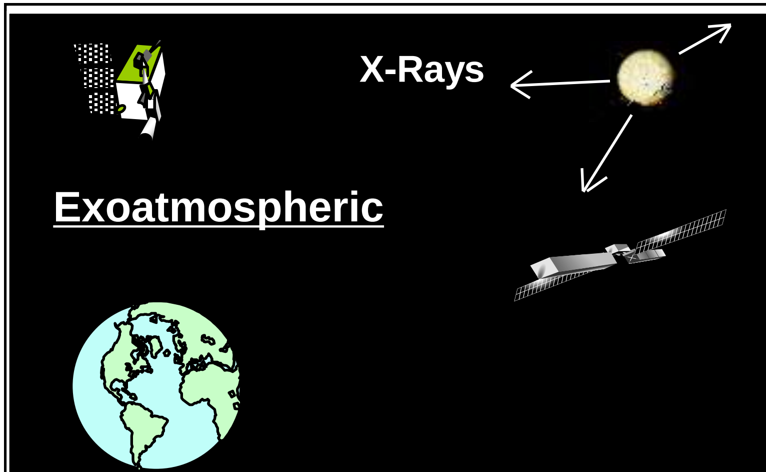


- X-rays are absorbed near the burst.
- Radiation is generally less important than blast and shock.
- Fallout can irradiate personnel.

Endoatmospheric



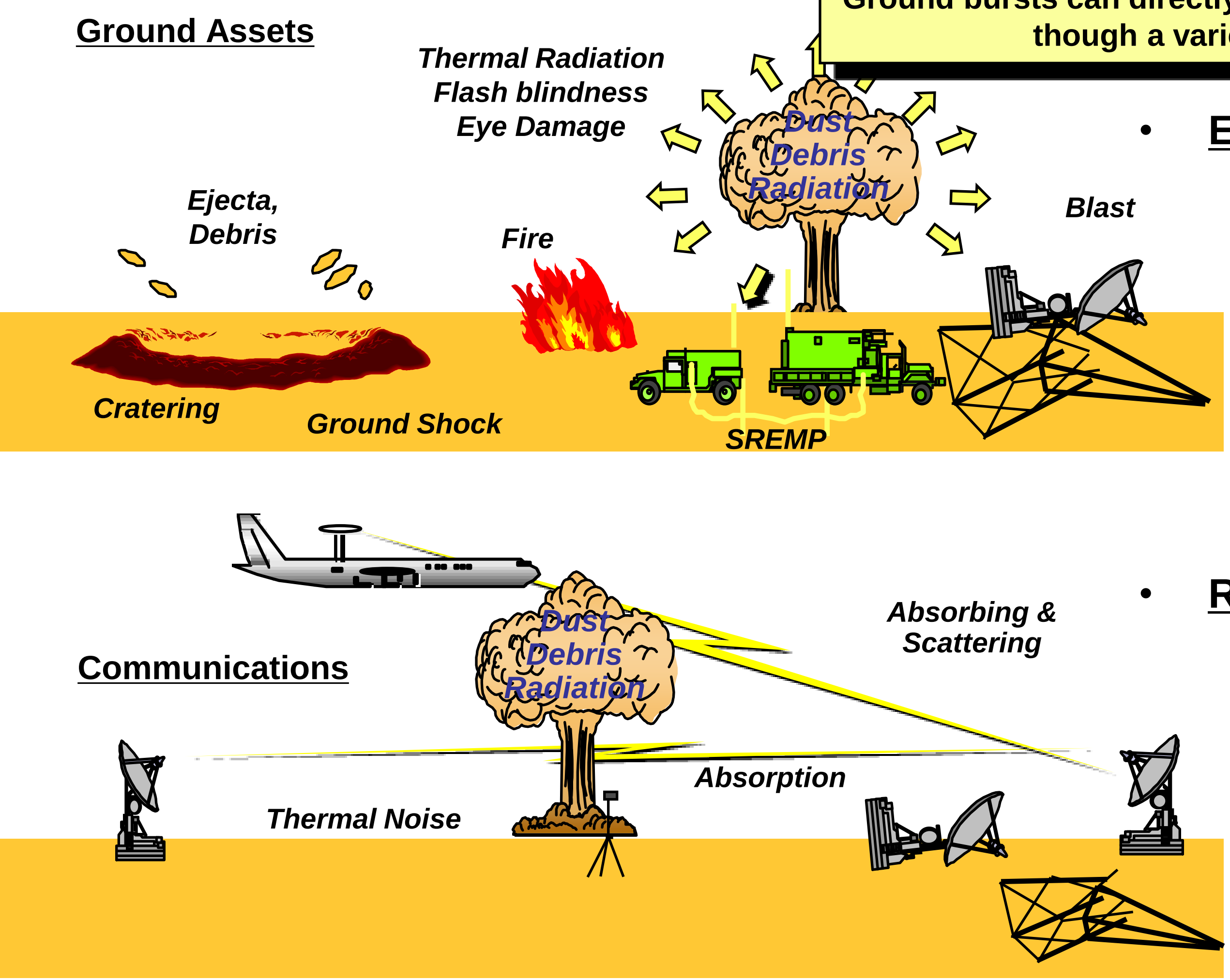
- Radiation (X, γ) ionizes upper atmosphere.
- Ionized layer produces electromagnetic pulse (EMP) that propagates down to ground.



- Radiation (x, γ, n) travel through vacuum to reach space assets
  - Dies off as $1/R^2$
  - Radiation can kill electronics directly (TREE) or create current pulses in wires (SGEMP) that kill electronics.
- Bomb debris are contained in earth's magnetic field.
  - This interacts with low orbit assets (total dose) to cause long term kill in days, weeks or months.

Direct Damage to Ground Nodes: Surface Burst

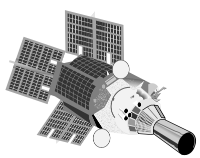
Ground bursts can directly damage or impair system ground nodes though a variety of coupling mechanisms



- **Effects:**
  - Blast & Shock
  - Cratering
  - Thermal
  - Dust
  - Absorption & Scattering
  - Fallout
  - Initial Nuclear Radiation
  - Source Region EMP
- **Results**
  - Destruction of C3I
  - Denial of Use of Assets
  - Loss of LOS Communications
  - Loss of Ability to Communicate

Direct Damage to Space Nodes: Exoatmospheric Bursts

Exoatmospheric bursts can directly impair space nodes through a variety of radiation damage mechanisms



NATURAL SPACE ENVIRONMENTS

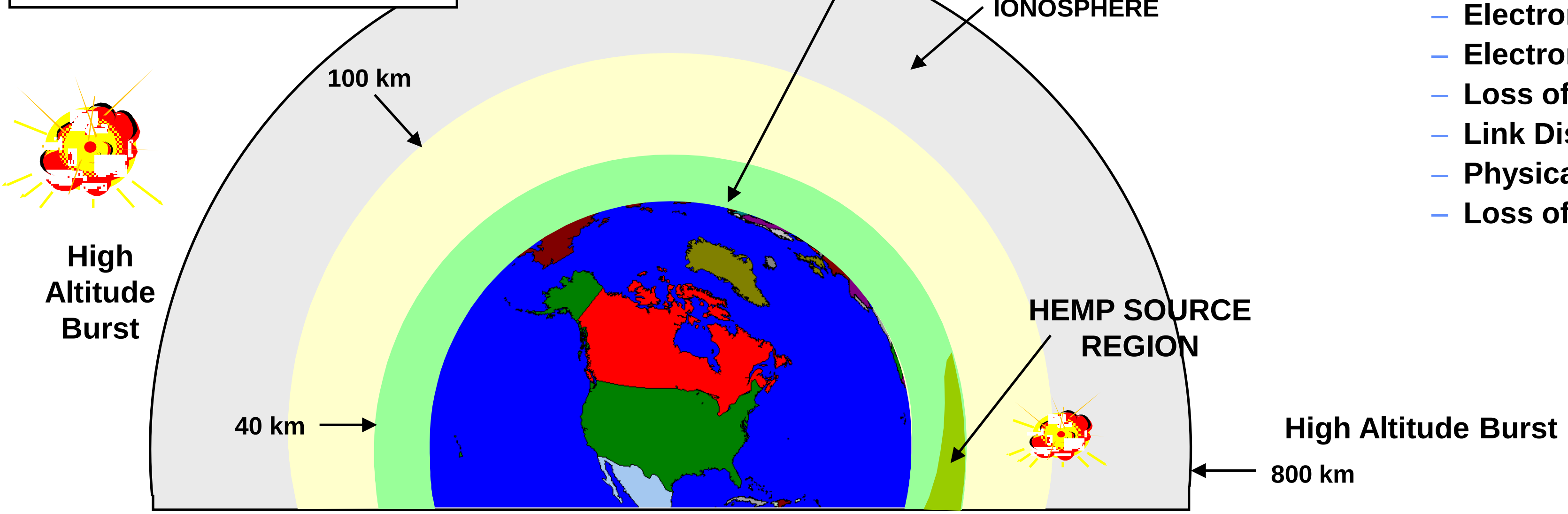
- Trapped Electrons & Protons
- Solar Event Protons
- Galactic Cosmic Rays

Exoatmospheric Burst

- Neutrons
- γ-rays
- X-rays
- Radioactive Debris

ATMOSPHERIC EFFECTS

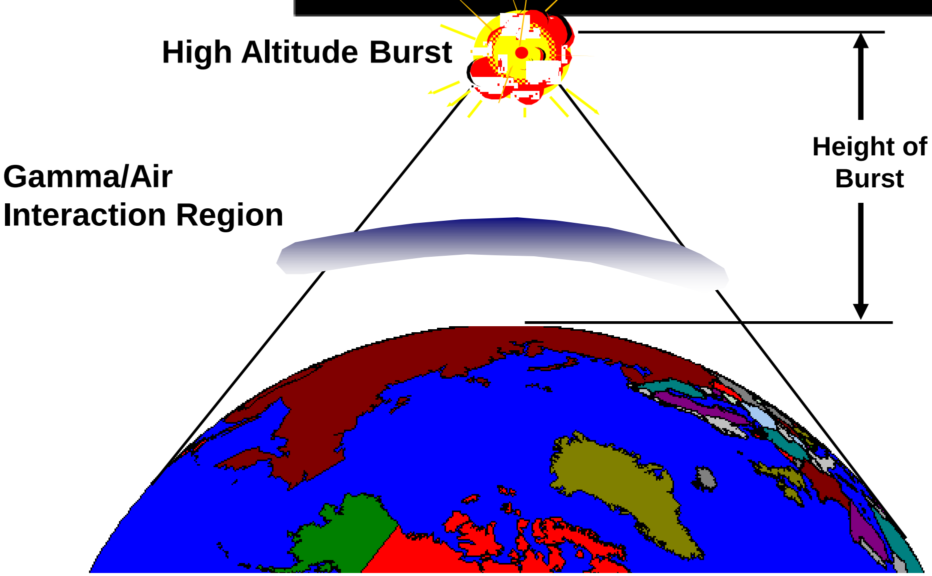
- Disturbed Propagation Paths
- Nuclear Backgrounds



- **Effects:**
  - TREE Dose Rate
  - TREE Total Dose
  - TMS
  - SGEMP
  - Debris Gammas
  - Debris Electrons
- **Results**
  - False Targets
  - Electronics Upset
  - Electronics Burnout
  - Loss of Track
  - Link Distortion
  - Physical Damage
  - Loss of Space Node

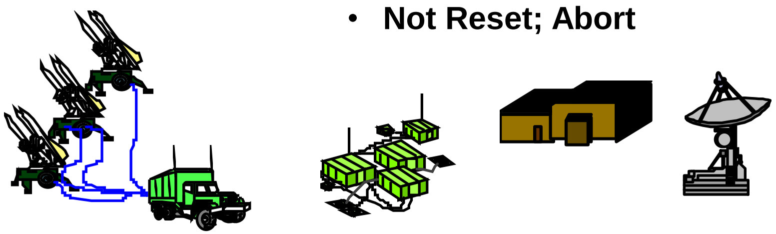
Damage to Ground Nodes: EMP from High Altitude Bursts

High Altitude Bursts can also impair Ground and/or Space nodes through the long range effects of EMP



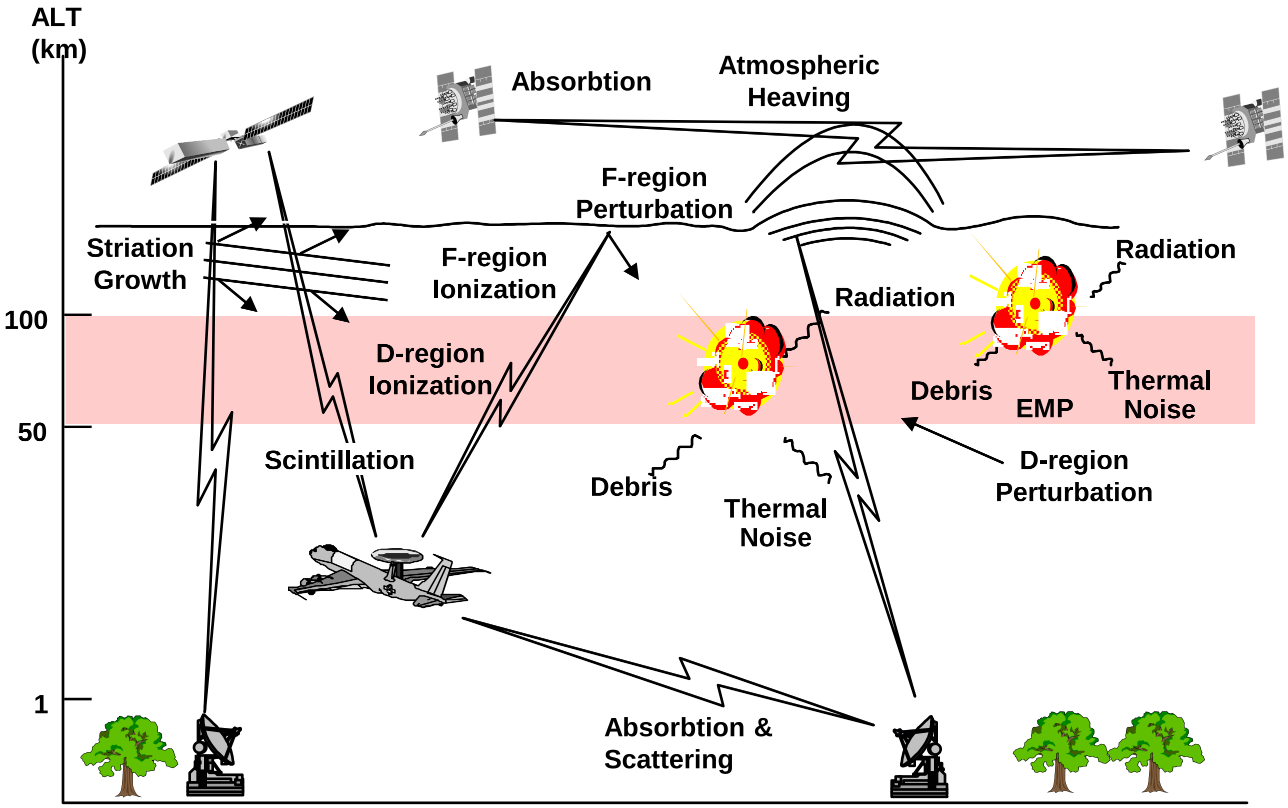
HEMP Component	System Size		
	10s of meters (A/C Missiles)	~200 meters (Bldgs/Long Lines)	10s of km (Long Lines)
Early-Time	✓	✓	✓
Intermediate-Time		✓	✓
Late time MHD-EMP			✓

- <u>Permanent Damage</u>
  - Device or Component Failure
  - Not Correctable
  - Loss of Function
  - Key Issue: Mission Impact
    - Abort
    - Degradation
    - None
- <u>Upset</u>
  - Inadvertent Change of System State
  - Overt or Latent
  - Temporary Condition
  - Key Issue: Mission Impact
    - Reset; No Impact
    - Reset; Degradation
    - Not Reset; Degradation
    - Not Reset; Abort



Indirect Operability Impact: Link Degradation

Nuclear bursts can also indirectly interfere with operations by disturbing sensor/communication links



- Effects
  - Optical Background
  - Radioactive Debris
  - Blackout
  - Scintillation
- Results
  - Target Masking
  - False Targets
  - Link Failure
  - Increased Errors

System Architecture/Operational Approaches

System architecture/operational approaches can be extremely effective at mitigating the effects of nuclear weapons

Mitigation Approach	*System Architecture*
• Proliferation/Distribution of Assets	• TRIAD
• Threat Avoidance	• Mobile Facilities/Command Posts • Satellites in GEO Orbit
• Robust Links	• Network Insensitive to Node Loss Signal Processing (Software/ Hardware)
• Redundancy	• Multiple Redundant Satellites • Multiple Radar Systems

Hardening of Surface Assets to Direct Effects

Near surface assets can be hardened to improve their survivability to near-surface bursts

Thermal Pulse

- Use Reflective Coatings
- Provide Insulating Material
- Use Ablator or Sacrificial Shield
- Build Underground

Air Blast

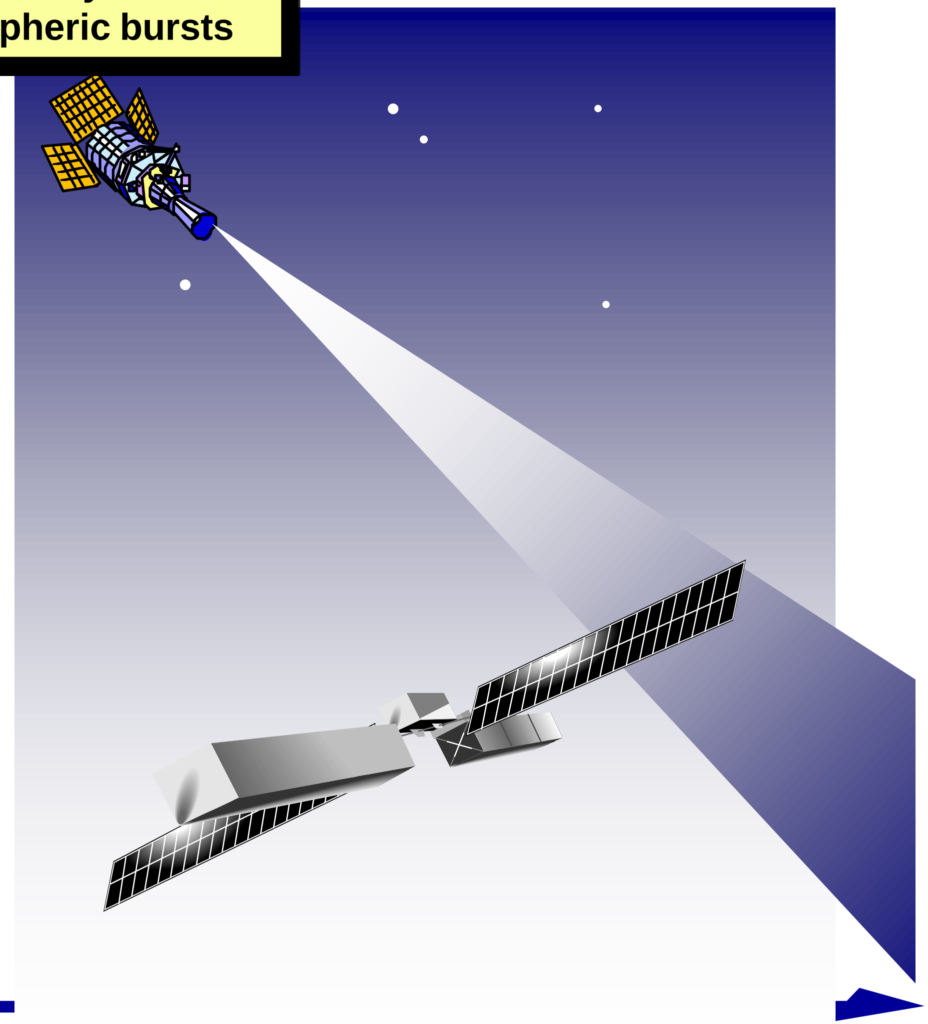
- Provide Aerodynamic Shape
- Increase Physical Strength or Mass
- Build Underground
- Use Significant Tie Downs

Ground Shock/Cratering

- Increase Physical Strength
- Design Elastic Response
- Reduce Resonant Modes
- Improve Ductility /Flexibility
- Provide Shock Isolators
- Build Very Deep Underground

Hardening of Space Assets to Direct Effects

Space assets can be hardened to improve survivability and operability against the radiation effects of exoatmospheric bursts



SGEMP

- Radiation Shielding
- Circuit Design
- EM Shielding Topology

Thermo-mechanical

- Shielding
- Material Selection

Dose Rate (TREE)

- Radiation Shielding
- Parts Selection
- Circuit Design
- Circumvention/Reset

Total Dose

- Radiation Shielding
- Hardened Parts

Hardening of Assets to EMP

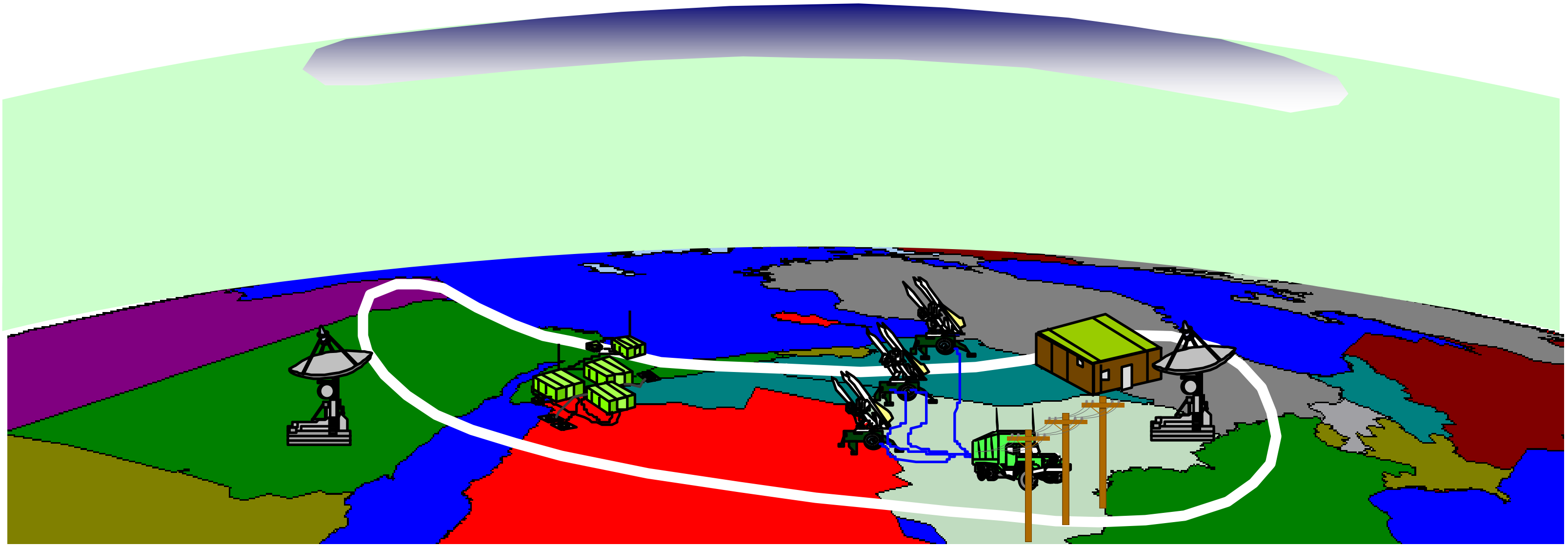
Near surface assets can also be hardened against the effects of EMP from a high-altitude burst

Shielding

- Faraday Cage
- Point of Entry (POE) Control
- EM Gaskets
- Connector Shells
- Rule of Thumb:
  20 dB per Shield ($I_{out}=10^{-2} I_{in}$)

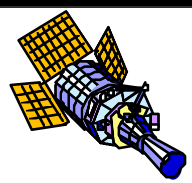
Interface Design

- Terminal Protection Devices
- Filters
- Current Limiting
- Transformer Isolation



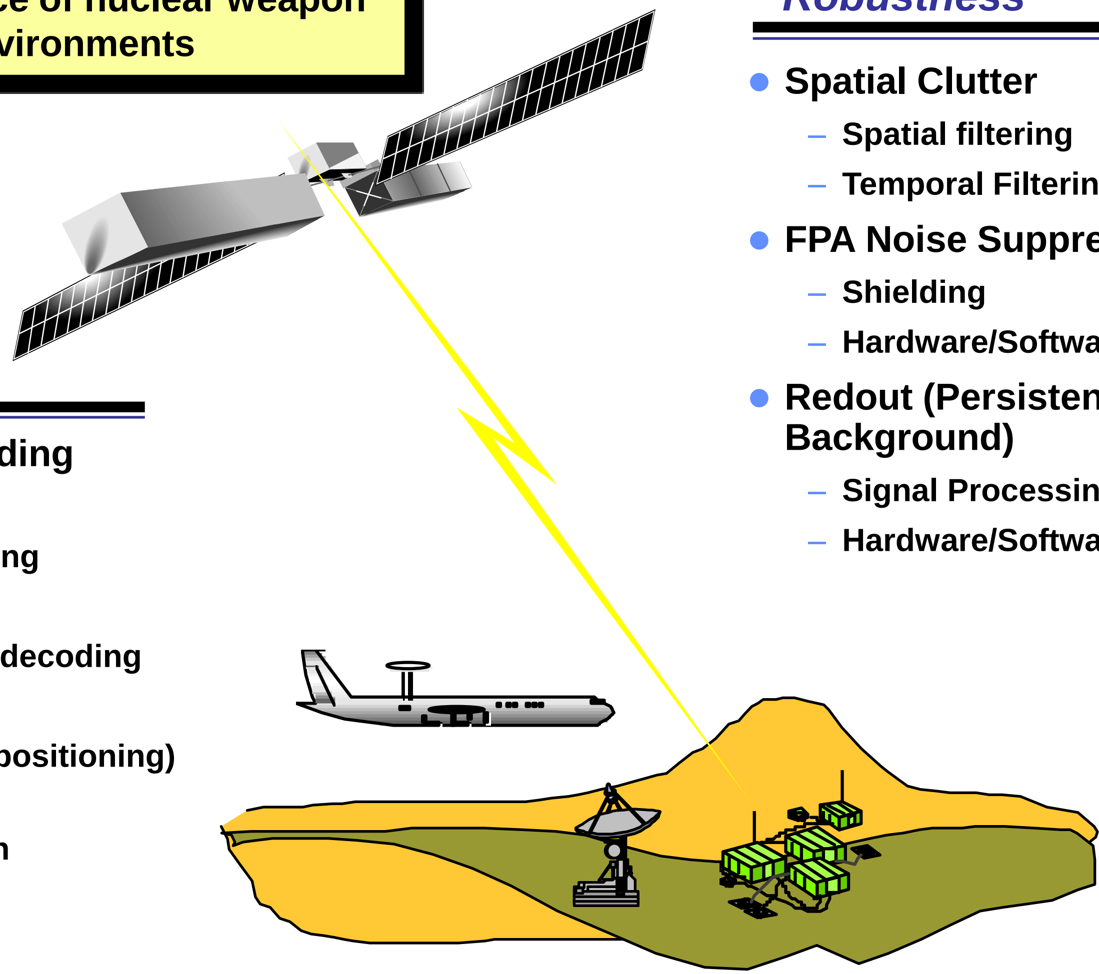
Robust Links

Special design techniques can improve link performance in the presence of nuclear weapon induced noise environments



Communication Link Robustness

- Scintillation/Amplitude Fading
  - Modulation selection
  - Low rate encoding/ decoding
  - Message repetition
  - Error correction encoding/decoding
  - Long interleaving
  - Spatial diversity (antenna positioning)
- Blackout
  - Carrier frequency selection
  - Adaptive equalization



Sensor Link Robustness

- Spatial Clutter
  - Spatial filtering
  - Temporal Filtering
- FPA Noise Suppression (e^-, γ)
  - Shielding
  - Hardware/Software
- Redout (Persistent Optical Background)
  - Signal Processing
  - Hardware/Software

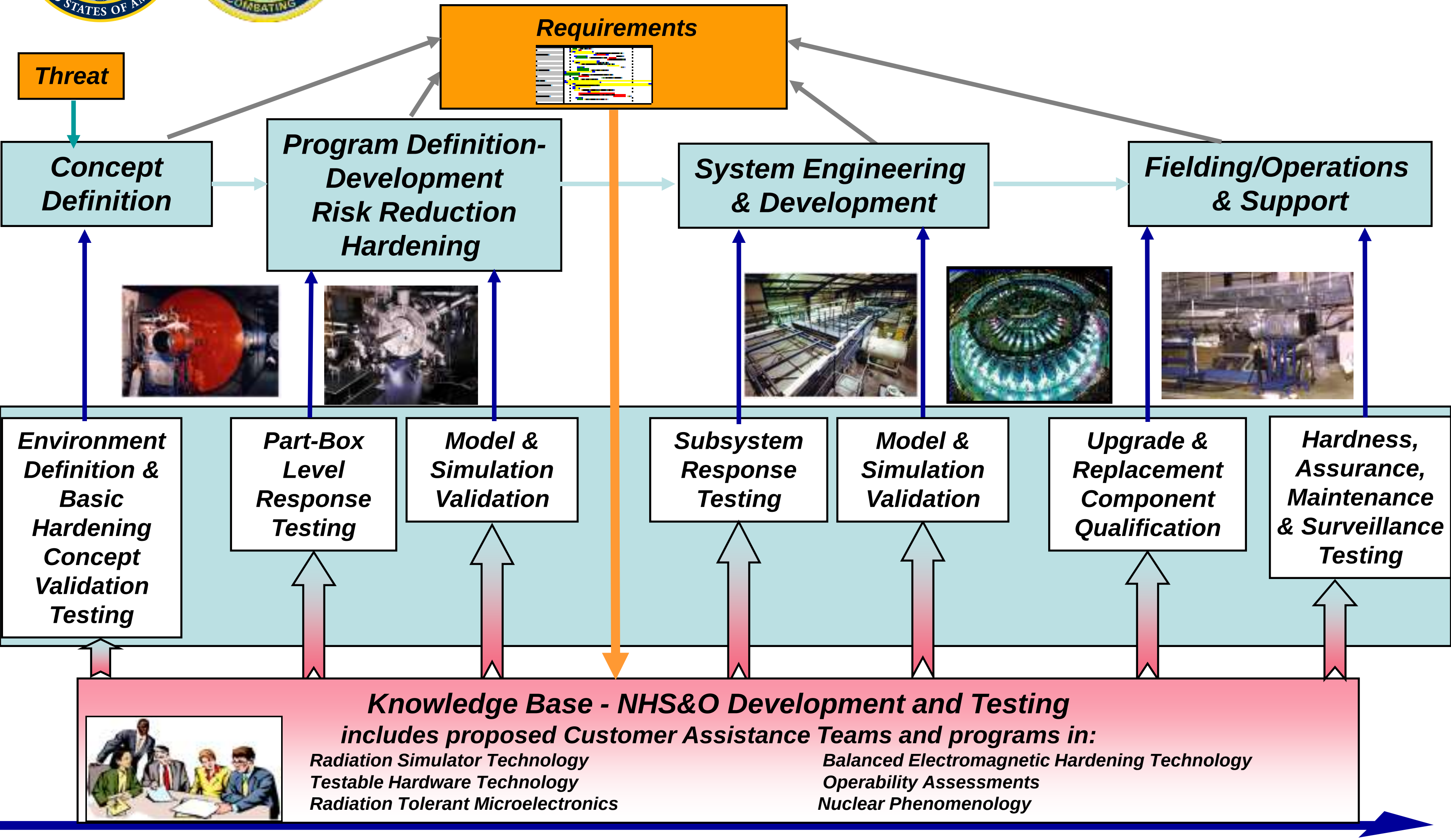
Core Competencies for Survivability

- Weapon outputs to determine requirements
- Rigor in design phase (standards, protocols)
- Technical strategy for each NWE environment
  - Phenomenology-based understanding of nuclear effects
  - Advanced experimentation capability for nuclear weapon environments and effects modeling validation
  - Nuclear survivability hardening technologies
- Sustained expertise in research, development, test, and evaluation

Relative Survivability Criteria by System

System Type	X-rays	Neutrons	Total Dose	Gamma Rate	EMP	Air Blast	Thermal
Strategic Systems							
Missiles	M	M	M	M	Mil Std	L	M
RV/RB	H	H	H	H	Mil Std	L-M	H
Satellites	L-M	L-M	L-M	L-M	-	-	L-M
C3I	-	M	M	M	Mil Std	M	M
Submarines	-	-	-	-	Mil Std	-	-
Tactical Systems							
Missiles	L	M	M	M	Mil Std	M	M
Airborne	-	M	M	M	Mil Std	L-M	L-M
Fixed Installations	-	L-M	L-M	L-M	Mil Std	M	M
Ships	-	L-M	L-M	L-M	Mil Std	M	M
Vehicles	-	L-M	L-M	L-M	Mil Std	M	M
Exposure Levels	cal/cm^2	n/cm^2	rads(Si)	rads(Si)/s	Mil Std	psi	cal/cm^2
H - High	>0.1	$>10^{13}$	$>10^4$	$>10^9$	2169B	>10	>80
M - Medium	0.01-0.1	10^{11}-10^{13}	$2X10^3$-10^4	10^7-10^9	2169B	2 - 10	10 - 80
L –Low	<0.01	$<10^{11}$	$<2X10^3$	$<10^7$	2169B	<2	<10

Simulators Play Critical Roles at Each Life-Cycle Stage



Nuclear Weapons Effects Simulators

Test	Type of Simulator	Size of Test
X-ray Effects (Hot)	Low Voltage Flash X-ray Machines	Components and small assemblies
X-ray Effects (Cold)	Plasma Radiators	Components
Gamma Ray Effects	Flash X-Ray Machines Linear Accelerator Fast Burst Reactor	Components, circuits & equipment
Total Dose Gamma Effects	Cobalt 60 Fast Burst Reactor	Components, circuits and equipment
Neutron Effects	Fast Burst Reactor	Components, circuits & equipment
Blast Effects (Overpressure)	Small Shock Tubes Large Shock Tubes HE Tests	Components, circuits & equipment Small systems & large equipment Vehicles, radars, shelters, etc
EMP	Pulsed Current Injection Free Field	Equipment, large components Systems
Thermal Effects	Thermal Radiation Source Flash Lamps & Solar	Equipment, large components Components & materials
Shock Effects (Dynamic Pressure)	Large Blast Thermal Simulator (LBTS) Explosives	Equipment, large components Systems

Nuclear Weapons Effects Simulators

Nuclear HEMP Military Standards

- MIL-STD-2169B HEMP Environment
- MIL-STD-188-125-1 Fixed C4I Facilities
- MIL-STD-188-125-2 Transportable C4I Facilities
- MIL-HDBK-423 HEMP Protection C4I Facilities
- MIL-STD-464 System E3 Requirements
- MIL-STD-461F Equipment EMI Emissions/Susceptibility
- MIL-STD-3023 Aircraft HEMP Protection (draft)
- MIL-STD-XXXX Maritime HEMP Protection (FY09 start)

Summary

- Characteristics of nuclear weapons detonations are well understood
- Mission Impact of Nuclear Weapon Detonation is real and we know how to mitigate the threat
  - Engineering aspects well understood
  - Testing options are available
- Hardening is affordable if addressed up front
- Radiation hardening is a part of balanced survivability