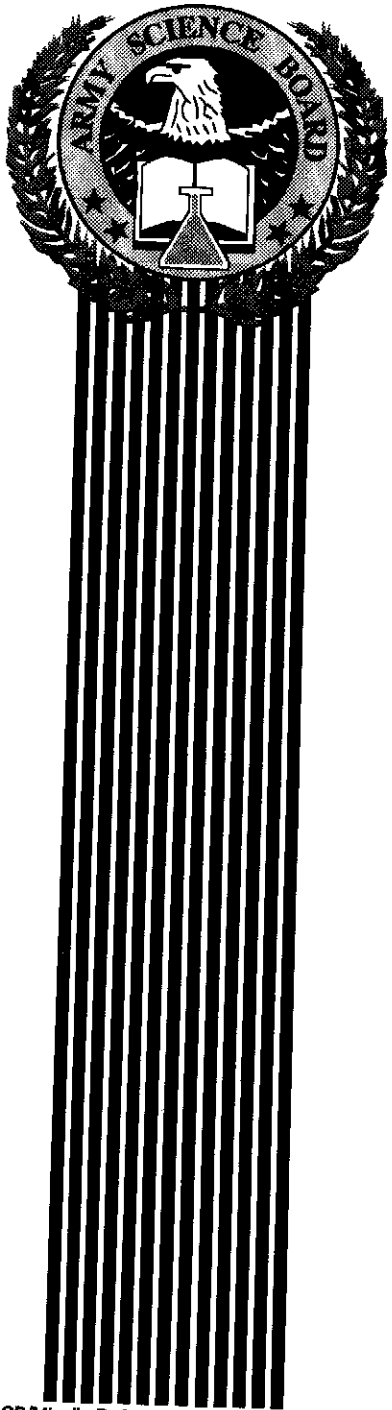

TMD Lethality

Independent Assessment Study

Final Report
April 1996

Prepared for
USASSDC/CSSD-ZA
LTG Jay M. Garner

Prepared by the
Army Science Board
Missile Defense Issue Panel

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TMD Lethality – Independent Assessment Study

Study Members

Dr. Chuck Nardo – Aerotherm Corporation/DynCorp – Chair

Dr. Richard Haley – Consultant

Dr. Wade Kornegay – MIT/LL

Dr. Annetta Watson – Oak Ridge National Lab

Mr. Wayne Winton – Sparta

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	Mr. Roy Nichols – Nichols Research
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	Mr. Bill Brown – USASSDC/WDC
Sponsor:	LTG. Jay Garner – USASSDC
Cognizant Deputy:	Dr. Darrell Collier – USASSDC
ASB:	
Executive Secretary:	Col. Herb Gallagher
Missile Def. Panel Chair:	Dr. Foster Rich – Booz-Allen

TMD Lethality – Independent Assessment Study

Terms of Reference (TORs)

- The TORs required the study group to:

  A. Examine and report on the state of efforts recommended by the 1993 Missile Defense Summer Study

  B. Identify other lethality mechanisms that should be considered when HTK cannot be assured

  C. Investigate and recommend second-generation lethality programs that should be implemented to counter proliferate target sets (including, ERS, PA, CM, and UAVs)

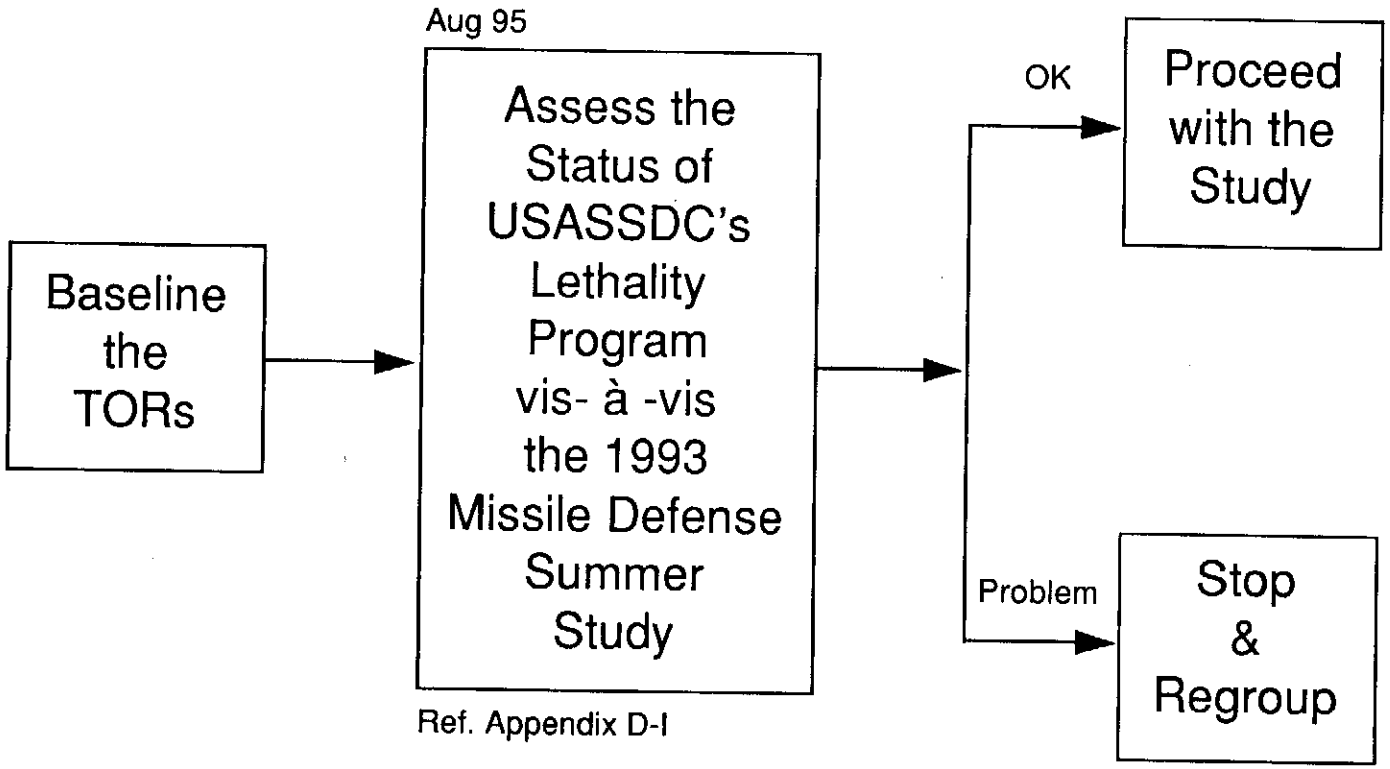
TMD Lethality – Independent Assessment Study

Summary of Meetings

1-2 Aug 95	USASSDC/ Huntsville	Kickoff and USASSDC perspectives on Intelligence and Lethality Lead: Nardo/Finamore
12-13 Sep 95	Pentagon	Intelligence/Threat Lead: Haley/Finamore
8-9 Nov 95	ERDEC	C/B Overview Lead: Watson/Finamore
22-25 Jan 96	LLNL	BMDO Lethality Lead: BMDO & USASSDC (Dr. R. Becker)
28-29 Feb 96	USASSDC/ Huntsville	Final Questions/Executive Meeting Lead: Nardo/Finamore

TMD Lethality – Independent Assessment Study

Study Panel's Logic Flow



TMD Lethality – Independent Assessment Study

1993 ASB Summer Study on Missile Defense*

1993 Lethality Status Assessment	1996 Status
Lethality Program Has Been Very Productive, However, Additional Work is Required	**Many Tests Accomplished, Still Incomplete**
• Quantitative rationale for ORD performance requirements lacking – impacts cost	ORD Modified, Requirement = Capability
• Hit-to-kill most promising solution to destroy warheads, but currently high risk technology	PAC-3/THAAD Progress = Lower Risk
• Fragment interceptor warhead will have limited effectiveness against submunitions	Still True
• Lethality against cruise missiles carrying chemical or biological warheads not being addressed	Still True
• TBM kill assessment capability does not support shoot-look-shoot or multi-tier engagement	S-L-S Fails Only for Hit Without Kill

*Reference Appendix D-1

TMD Lethality – Independent Assessment Study

1993 ASB Summer Study on Missile Defense*

1993 Lethality Recommendations	Current Status
• Reexamine operational and technical requirements definition – Develop quantitative foundation based on tradeoffs among performance, cost, schedule, and risk	* Not accomplished, probably impractical (lacking lethality phenomenology)
• Strive for direct hit-to-kill solution, with fragment warhead augmentation as a hedge	* No promising fragment warhead concepts identified
– Initiate next-generation HTK technology program; recommend Tri-Service approach	* Services lethality coordinated, but not an integrated program
– Allocate resources to HWIL capability testing at MRDEC	* HWIL guidance testing accomplished
– Increase lethality testing, including major activity for cruise missiles	* Many tests, but no effort relevant to CM C/B warheads
– Undertake integrated kill assessment effort	* Not being done
– Use systems analysis and engineering for quantitative investment guidance	* Not being done; acquisition milestones and budgets are driving the work

*Reference Appendix D-1

TMD Lethality – Independent Assessment Study

Observations

- The lethality recommendations of the 1993 ASB Summer Study were largely overtaken by events
  - BMD budget reductions, changes in priorities
- Consequently:
  - BMDO-funded lethality technology programs have ceased to exist. ***All*** lethality priorities/funding now come through program offices, focused on meeting PAC3 and THAAD acquisition milestones.
  - There is ***no*** R&D funding for next-generation lethality technologies as related to chem/bio submunition warheads
  - There has been ***very little*** work done with respect to TMD lethality against CMs or UAVs... and ***none*** for C/B warheads
  - There has been ***very little*** work done with respect to lethality, persistence, dispersion, and/or neutralization of chem/bio agents in the HTK scenario

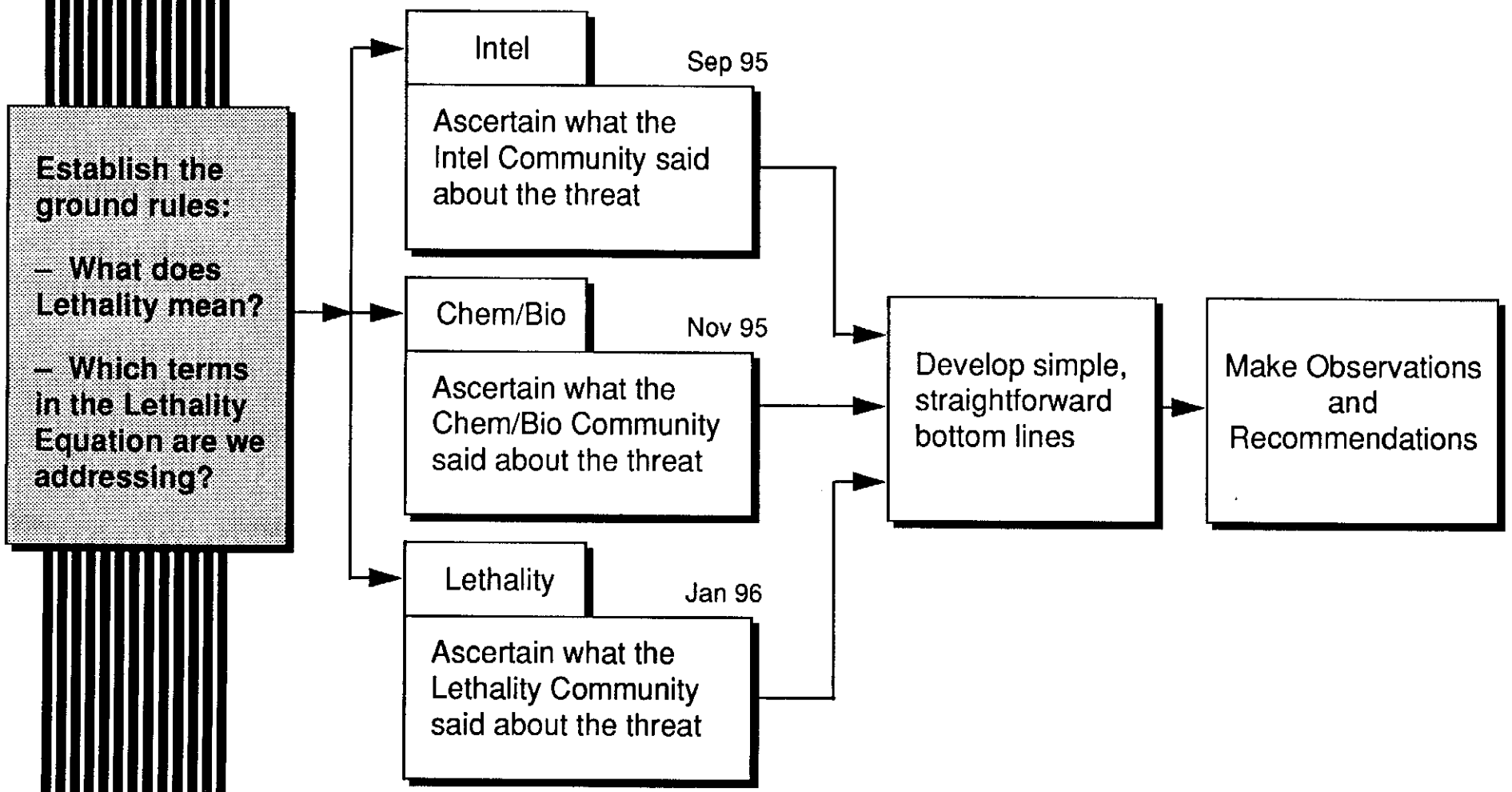
TMD Lethality – Independent Assessment Study

Redefinition of ASB Lethality Study Objective

- Stop and Regroup
  - The good news is that the Study Panel believes SSDC lethality test results to date support the notion that the U.S. can defeat TBM nuclear and unitary C/B threat payloads and can destroy a significant fraction of the submunitions in a TBM C/B submunition warhead
  - The bad news is very little else has been done. No promising and practical concepts have been identified for dealing with residual C/B submunitions surviving a TBM engagement, and no work has been done on lethality against CM/UAV C/B warheads (unitary or submunition).
- Redefinition of Study Objective
  - We decided to focus on understanding what is known about the C/B submunition threat and delivery systems for employing this threat in the theater, the phenomenology of C/B agents, and lethality related to those agents, and from this, recommend priorities for future SSDC lethality programs

TMD Lethality – Independent Assessment Study

Study Panel's New Logic Flow



TMD Lethality – Independent Assessment Study

Ground Rules

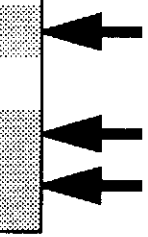
- What does Lethality mean?
  - The Study Panel embraced the Lethality Community's published Program Doctrine:
    - A hit is not necessarily a kill
    - The objective is to kill the payload: not the RV
    - The program establishes the criteria (mass, velocity, hit point) necessary to achieve desired outcome
    - The selected kill modes should be insensitive to variation in the target: not dependent on a specific target characteristic
    - Lethality requires a full body of evidence/experience: not simply flight tests nor sled tests, but an entire phenomenology

TMD Lethality – Independent Assessment Study

Ground Rules (concluded)

- Which terms in the Lethality equation are we addressing?

P_k^* = [Acquire, Track, Shoot] (P_k) * [Interceptor – Reliability – Propulsion – G&C – Seeker] (P_k) * [End Game Engagement – **Threat payload** – Countermeasures – **Interceptor warhead** – **Threat delivery system**] (P_k)

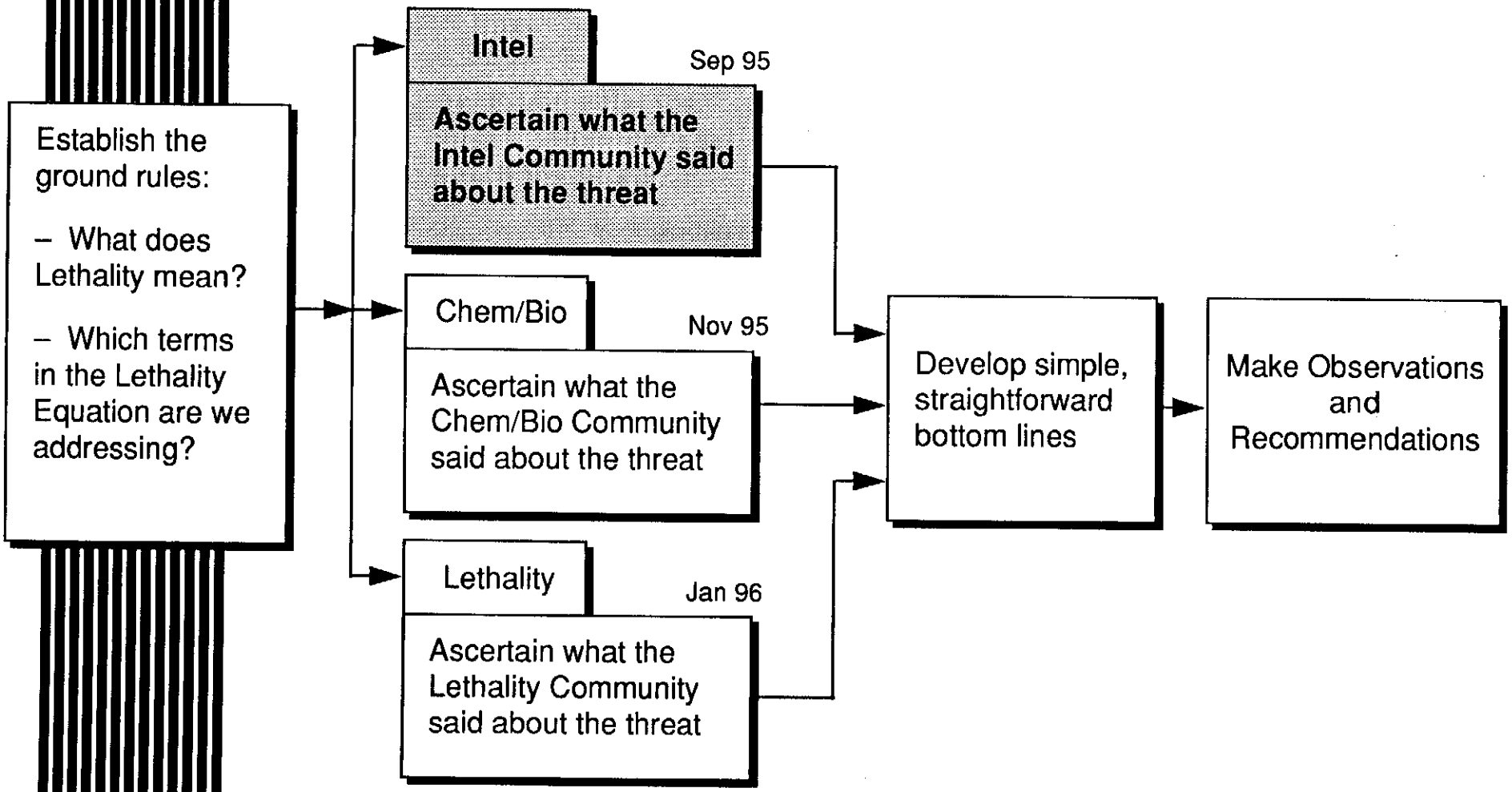


- We limited ourselves to:
  - Threat payloads (i.e., nuclear, unitary, chem/bio, SM)
  - Interceptor warhead (fragmentation, HTK)
  - Threat delivery system (TBM, maneuvering TM, CM, UAV)

* Probability of Kill, P_k, generalized equation, not meant to be complete

TMD Lethality – Independent Assessment Study

Study Panel's New Logic Flow



TMD Lethality – Independent Assessment Study

- **Threat matrix mix:**

Payload Weapon of Mass Destruction	Payload Configuration	Probable Delivery System
Nuclear	Unitary	TBM
Chemical/Bio Toxins	Unitary, Submunitions	TBM, CM/UAV
Bio Infective Organisms	Unitary, Submunitions	TBM, CM/UAV

- Threat payload screening criteria:
  - Probability of intercept
  - Probability of complete payload destruction, if intercepted
  - Payload technical sophistication
  - Delivery system technical sophistication
  - Payload manufacturing precursor indicators
  - Weapon used prior to U.S. deployment
  - Probable target areas
  - Objectives of threat

TMD Lethality – Independent Assessment Study

What the Intel community said about TBMs:

P_k

End Game Engagement
- – Threat payload
- – Countermeasures
- – Interceptor warhead
- **– Threat delivery system** ←

- Over two dozen potential threat countries have capability (not including the export factor)
- Existing launchers are in the 100s
- Existing missiles are in the 1000s
- Ranges vary from 50-3,100 km
- Capable of carrying any type of payload
- Targets vary from counterforce to countervalue to terrorist

TMD Lethality – Independent Assessment Study

What the Intel community said about UAVs/CMs:

P_k

End Game Engagement
- Threat payload
- Countermeasures
- Interceptor warhead
- **Threat delivery system** ←

- Over two dozen potential threat countries have capability (not including the export factor)
- Existing launchers are in the 100s
- Existing missiles are in the 1000s
- Ranges vary from 40-1500 km
- Capable of carrying any type of payload
- Requires less infrastructure and O&M (vis-à-vis TBMs)
- Technically less stressing (vis-à-vis TBMs)
- Hard to detect
- Technology more available
- Typically less expensive
- Targets vary from counterforce to countervalue to terrorist

TMD Lethality – Independent Assessment Study

What the Intel community said about chem/bio payloads:

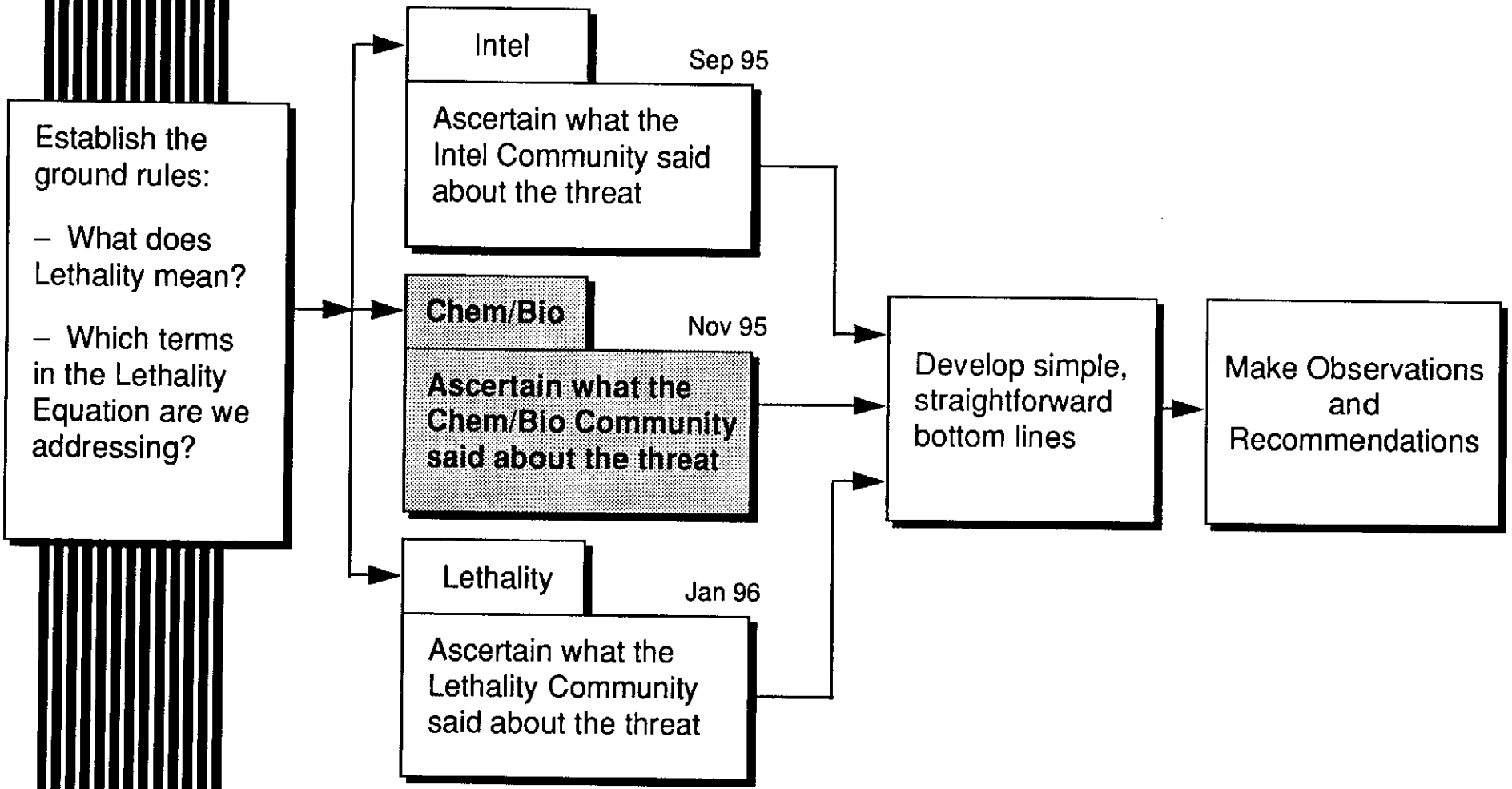
P_k

End Game Engagement
- **– Threat payload** ←
- – Countermeasures
- – Interceptor warhead
- – Threat delivery system

- Tracking two dozen programs; approximately half are of major concern
- Tracking the overlap of TBM/UAV/CM/chem/bio programs suggests ***5-10 major threat combinations***
- Chem/bio manufacturing plants are hard to detect, can be clandestine, and could be used without (or with little) warning vis-à-vis a nuclear threat
- Threat scenarios suggest countervalue (seaports, airports, staging areas), population centers and terrorist usage more likely than against forward military/theater operations

TMD Lethality – Independent Assessment Study

Study Panel's New Logic Flow



TMD Lethality – Independent Assessment Study

What the Chem/Bio community said about threat payloads and threat delivery systems:

P_k

End Game Engagement
- **– Threat payloads** ←
- – Countermeasures
- – Interceptor warheads
- **– Threat delivery systems** ←

- Submunitions and chem/bio agents go hand in hand (see Appendix D-2)
- Most chem/bio agents are easily manufactured
- Inability to provide real-time detection
- Significant work required to improve decon and passive protection
- Delivery systems span the gamut of "walk-ins, aircraft spraying, to TBMs with submunitions" (ideal for CM or UAV)
- Civilian populations in Theater are at significant risks
- Major psychological military weapon
- Fixed assets near Theater or in deployment areas at significant risk (sortie disruption)

TMD Lethality – Independent Assessment Study

- **Chemical Warfare Agents**

Agent	Symbol	Persistency	Rate of Action	LCt_{50} (mg-min/m^3)	Remarks/Source
Tabun	GA	Low	Very Rapid	135	Nerve
Sarin[a,b]	GB	Low	Very Rapid	70	Nerve
Soman[b]	GD	Moderate	Very Rapid	70	Nerve
GF	GF	Moderate	Very Rapid	NA	Nerve
VX[a,b]	VX	Very High	Rapid	30	Nerve
Sulfur Mustard	H,HD	Very High	Delayed	1500	Blister
Lewisite	L	High	Rapid	1200-1500	Blister
Phosgene	CG	Low	Delayed	3200	Choking
Hydrogen Cyanide	AC	Low	Rapid	2000(@200 mg/m^3) 4500(@150 mg/m^3)	Blood

063-96

Footnotes:

[a]Iraqi arsenal (U.S. News & World Report, 11 Sep 95)

[b]ERDEC Foreign Intelligence Office (Ince, 95)

[c]BIDS design (Ness, 94)

Source: Medical Management of Biological Casualties Handbook 1993
U.S. Army Medical Research Institute of Infectious Diseases, Ft. Detrick, Frederick, MD

TMD Lethality – Independent Assessment Study

- **Biotoxins:**

Agent	Rate of Action	LD_{50} (μg/kg)	Remarks/Source
Botulinum[a,b,c]	Delayed	.001	Bacterium (Bacillus anthracis)
Gangrene[a]	Delayed	0.1-5.0	Bacterium (Clostridium perfringens)
Ricin[a,c]	Delayed	3.0	Seed of castor bean plant (Ricinus communis)
Saxitoxin[b]	Very Rapid	10.0 (inhal-2.0)	Marine dinoflagellate
Staphyloccus enterotoxin B[b,c]	Delayed	27.0	Bacterium (Staphyloccus spp.) (Rhesus aerosol)
Mycotoxin[a,b] (yellow rain)	Rapid	1210	Mold (Fusarium spp.)

063-96a

Footnotes:

[a] Iraqi arsenal (U.S. News & World Report, 11 Sep 95)

[b] ERDEC Foreign Intelligence Office (Ince, 95)

[c] BIDS design (Ness, 94)

Source: Medical Management of Biological Casualties Handbook 1993 U.S. Army Medical Research Institute of Infectious Diseases, Ft. Detrick, Frederick, MD

TMD Lethality – Independent Assessment Study

- **Bio Infective Organisms**

Disease/Agent	Incubation Time (days)	Persistence		Infection Route	Infectivity	Fatality Rate if Untreated (%)	Remarks
		Air	Ground				
Anthrax, pneumonic	1-6	hours–days	years in soil/water	Spores-inhalation	High; LD_2~10 spores LD_{50}~8-10K spores	80-100	1,2,3,4
Brucellosis	5-21	months if stabilized	months if stabilized	aerosol-inhalation eye membrane contact and/or skin cut	High; 1300 cells	2	3
Cholera	1-5	days	days-weeks in water	ingestion	Low; 10^8-10^{10} cells	25-50	2
Glanders	8-10	~days (if stabilized)	~days (if stabilized)	aerosol-inhalation	High; 3200 cells	"sometimes"	–
Plague, pneumonic	1-6	hrs in sun; days if stabilized	weeks in water or moist food	aerosol–inhalation mouth or throat membrane contact	High; 3000 cells	~100	2,3

064-96

TMD Lethality – Independent Assessment Study

- **Bio Infective Organisms (continued)**

064-96a

Disease/Agent	Incubation Time (days)	Persistence		Infection Route	Infectivity	Fatality Rate if Untreated (%)	Remarks
		Air	Ground				
Q fever	10-21	~days when dry	~days when dry	aerosol–inhalation; tick bites	High; 1-10 cells	1	–
Small pox	7-16	~weeks if stabilized	~weeks if stabilized	aerosol-inhalation	High; few virus particles	"Often"	–
Tularemia pneumonic	1-10	~weeks	~weeks; ~years in frozen meats	aerosol-inhalation; eye membrane contact	High - 50-100 cells	~30	2,3
		[easily killed by heat]					
Venezuelan equine encephalitis (VEE)	1-6	~hours	~hours to days	aerosol-inhalation; mosquito bite	High, 1 mosquito bite	< 1% Adults ~20% children	–
		[easily killed by heat]					

Remarks:

1. Iraqi arsenal (U.S. News and World Report, 11 Sep 95)
2. ERDEC Foreign Intelligence Office (Ince, 95)
3. BIDS Design (Ness, 94)
4. Weaponized anthrax likely to be highly virulent strains, 10^2 to 10^3 more potent than non-weaponized (endemic) strains (Armed Services Biomedical Research Evaluation and Medical Committee, 1993)

Sources:

U.S. AMR, 1993, Medical Management of Biological Casualties Handbook, U.S. Army Medical Research Institute of Infectious Diseases, Ft. Detrick MD
Sanford, J.P., 1995. "Biological Weapons," Dept. of Internal Medicine, University of Texas Southwestern Medical Center (5 Oct 95)

TMD Lethality – Independent Assessment Study

- **Chemical Warfare Agents – Developmental**

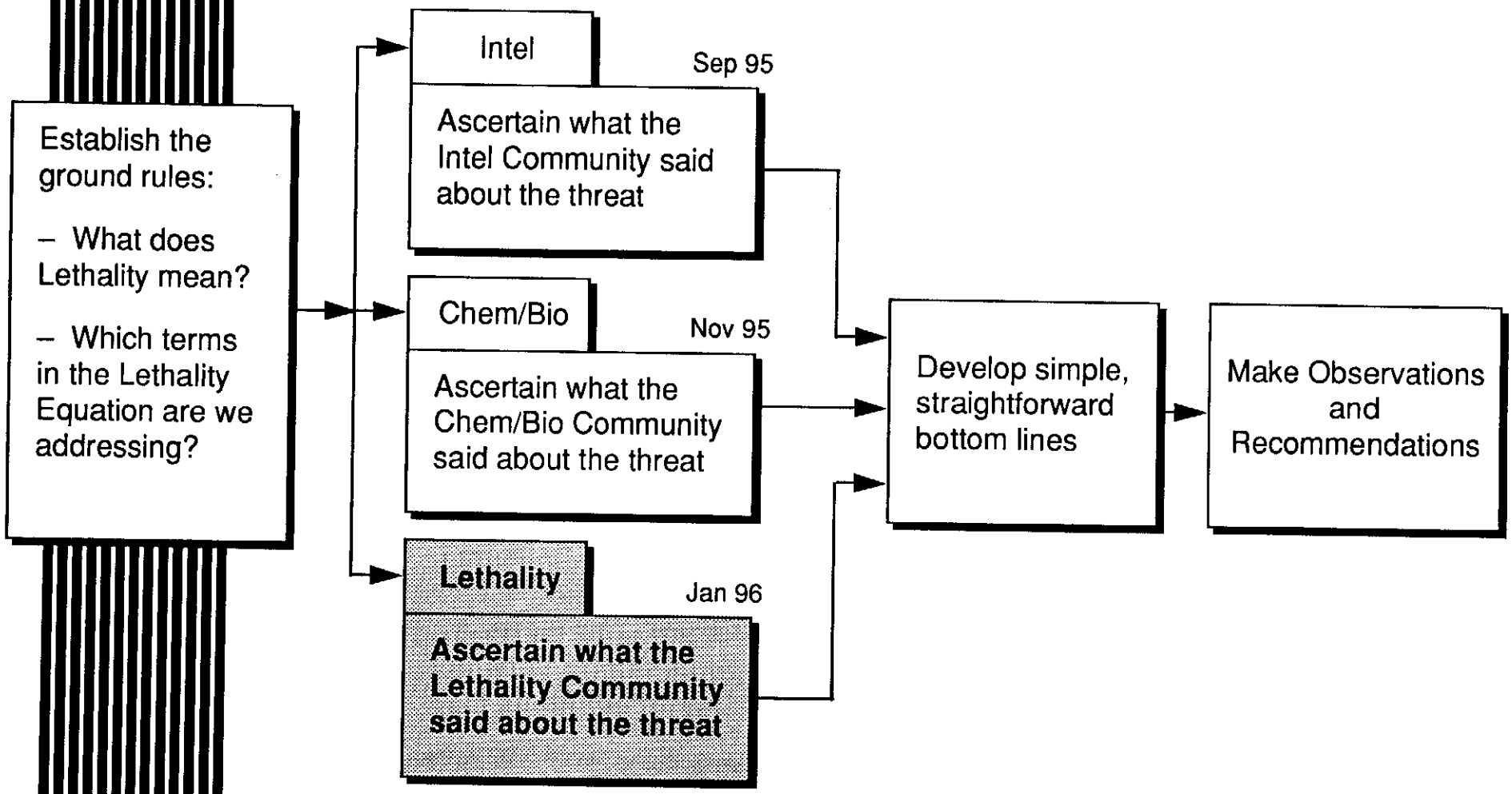
Agent	Action	Remarks
Novichok	Alleged nerve agent (FSU)	1
Antibiotic resistant plague	Enhanced microbe causing pneumonic plague; assume 90% fatality (FSU, Biopreparat)	1
Viruses (smallpox, Marburg, various influenza)	Virulent, contagious and highly fatal diseases; largely pneumonic (FSU)	2,3,4
Genetically modified microorganisms	Benign microbes genetically altered to produce toxins, venoms, etc.; advanced aerosol and environmental stability	3
Bioregulators	Disrupt normal body controls on blood pressure, heart rate, body temperature (FSU)	1,3
Toxins from various shellfish bacteria, algae, snakes, pufferfish	Naturally occurring venoms and neurotoxins; potent and stable under environmental conditions	3
Mixed agents	Enhanced disease infectivity or toxic action; e.g. lung irritant combined with pulmonary active pathogen or toxin	4

Remarks:

1. ERDEC Foreign Intelligence Office (Ince 1995)
2. Sanford 1995
3. Chemical and Biological Warfare Threat (Holahan, p.c.)
4. Armed Services Biomedical Research Evaluation and Medical Committee 1993

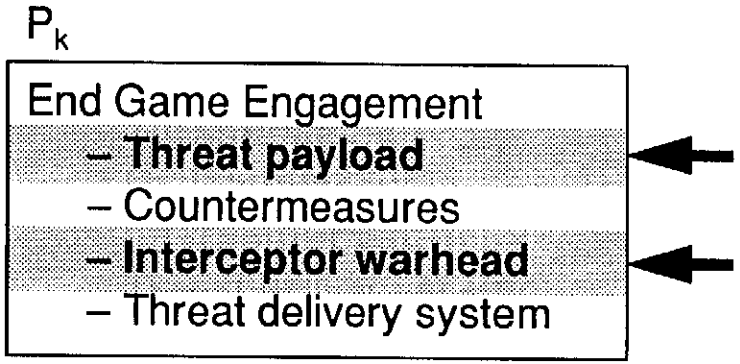
TMD Lethality – Independent Assessment Study

Study Panel's New Logic Flow



TMD Lethality – Independent Assessment Study

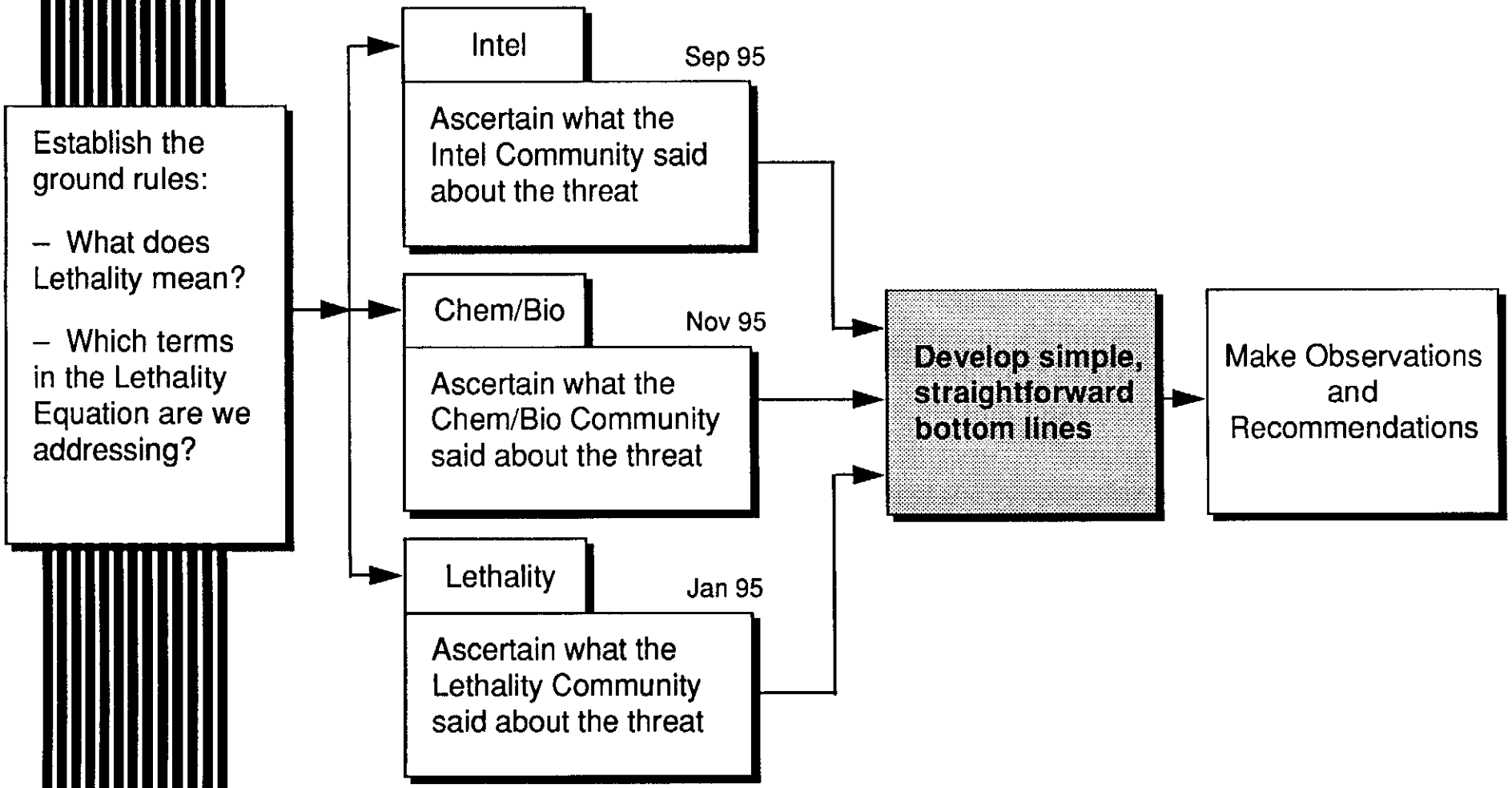
What the Lethality community said about threat payloads and interceptor warheads:



- Fragmentation and HTK warheads should be lethal against incoming nuclear and unitary payloads
- We can't kill all submunitions
- Hit the threat as high and hard as possible
- Need ***both*** passive and active defenses

TMD Lethality – Independent Assessment Study

Study Panel's New Logic Flow



TMD Lethality – Independent Assessment Study

- **The threat says:**

Payload Weapon of Mass Destruction	Probable Delivery System	Probability of Intercept	If Intercepted, Probability of Complete Payload Destruction	Payload Technical Sophistication	Delivery System Technical Sophistication	Payload Manufacturing Precursor Indicators	Weapon Used Prior to U.S. Deployment	Probable Target Areas	Objectives Of Threat
Nuclear	TBM	High	High	High	Med	High	Not Likely	Population Centers	Win The War
Unitary									
-Chem/Bio Toxins and	TBM	High	High	Low	Med	Low	Possible	All	Various
Bio Infective Organisms	**CM/UAV**	**Low**	**Low**	Low	Low	Low	Possible	All	Various
Submunition									
-Chem/Bio Toxins and	TBM	High	**Low**	Med	Low	Low	Possible	All	Various
Bio Infective Organisms	**CM/UAV**	**Low**	**Low**	Med	Low	Low	Low	All	Various

96-010

- **Bottom line: most stressing → SMs, chem/bio, CM/UAVs**

TMD Lethality – Independent Assessment Study

- **But our FY 96 funding is going here:**

	RANKING (JAN 96)	
	BMDO Integrated Priority List	Lethality Workshop FY96 Lethality Consensus
CBDE LOA	1	13
Secondary Evaporation	2	14
PAC-3 LFT&E	3	1
THAAD Lethality Development for MS II + PEGEM	4	2
Navy Area Lethality Criteria Development + PEGEM	5	3
Long-range TBM Level 3 Design	6	6
Navy LEAP Program Special Tasks	7	4
THAAD Added High-speed Testing	8	5
Integrated Rod Program	9	7
Application of Advanced Hydrocode Work	10	8
Navy Area Kill Criteria Development and Other Analyses	11	9
Bomblet Aerodynamic Thermal Demise Experiment	12	10
Navy LEAP Nonprogram Specific Tasks	13	11
Database Consolidation	14	12
CBW Agent Phenomenology + Other Issues for THAAD	15	–
Biological Agent Impact Test Response Series	16	15
Realistic Scaled Facilities	17	16
Special Range Instrumentation	18	17
Air Force ABI Lethality Program	19	–
Weapon Specific Lethality Program	20	–
Lethality Database Development	21	–

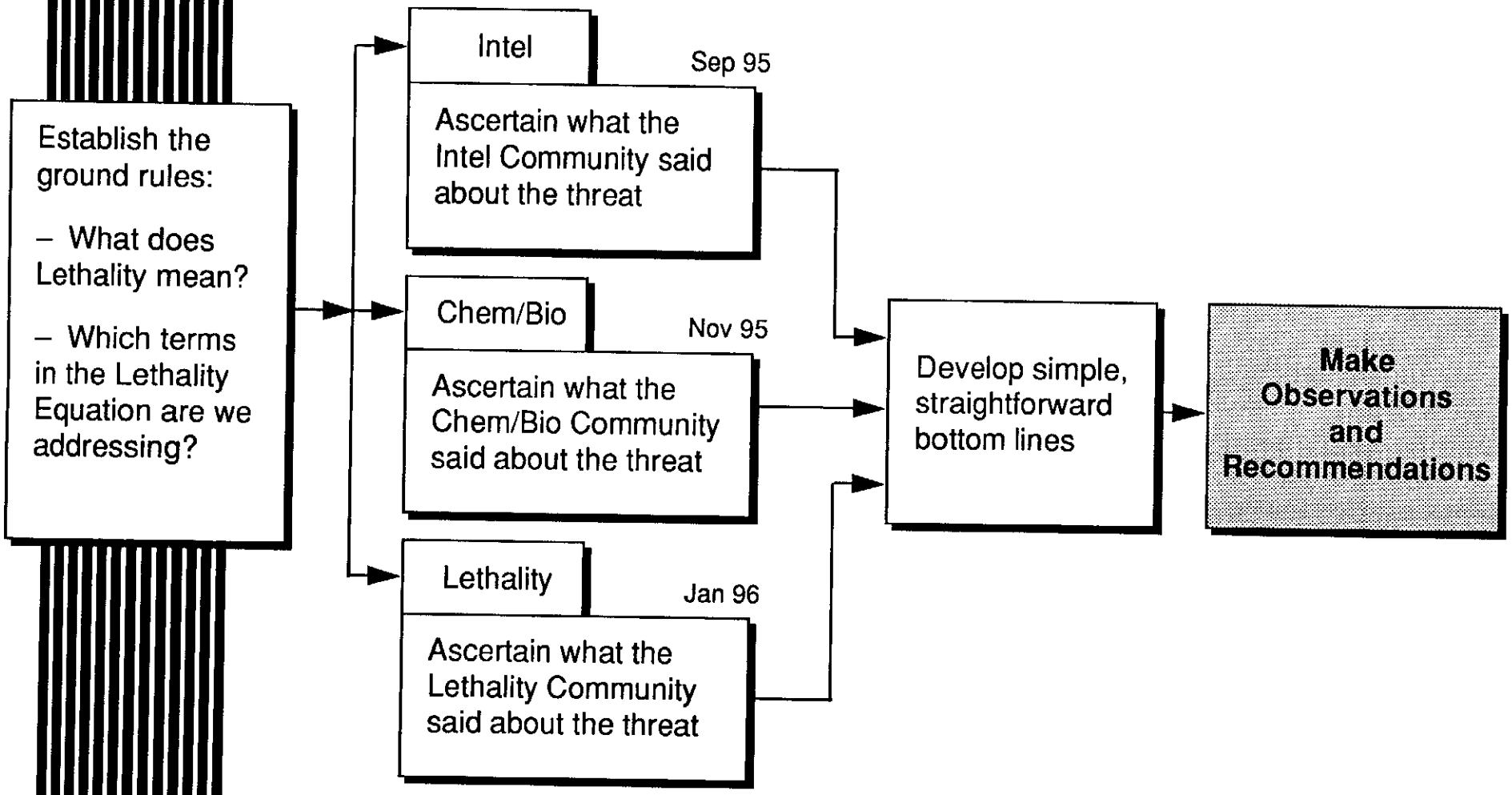
TMD Lethality – Independent Assessment Study

- **Bottom line "disconnects":**

  - No one is working the SM 100% kill problem
  - No one is working the CM/UAV defense issue
  - No long range strategic plan exists to address chem/bio in situ destruction
  - No mention of passive defenses
  - No mention of attack operations

TMD Lethality – Independent Assessment Study

Study Panel's New Logic Flow



TMD Lethality – Independent Assessment Study

- **Observations – Lethality: TBMs w/nuclear or bulk C/B payloads**
  1. Lethality phenomenology database on high-altitude intercept of nuclear and bulk C/B payloads is:
     - Extensive (many field tests)
     - Probably adequate (as a result of technological "backlog" of data)
     - Empirical (does not allow for extrapolation)
  2. THAAD and PAC-3 interceptors will destroy nuclear and bulk C/B payloads
  3. Neutralization of C/B payloads at TBM intercept altitudes relies on aerosolization phenomenology and ground concentration dilutions
  4. Aerosolization/dilution phenomenology will not be effective if:
     - C/B payloads carry "hardened" agents and/or mechanical stiffeners
     - C/B payloads are carried in low/slow delivery systems (A/C, CM, UAV, etc.)

TMD Lethality – Independent Assessment Study

- **Observations –Lethality: TBMs with submunitions**

1. Lethality against C/B submunitions is imperfect
   - Sufficient fraction of C/B SM will reach ground to generate fatalities/incapacitation
   - Area of lethal effects from individual surviving SM can be substantial depending upon agent

2. SM vary in "hardness" depending upon mission (i.e., military, terrorism, population centers, etc.); this will effect
   - Percent surviving
   - Footprint
   - Impact energy requirements (e.g., dry anthrax spores much "harder" than toxins)

TMD Lethality – Independent Assessment Study

- **Observations –Lethality Technology:**

The success of HTK technologies and our current, but limited, understanding of the lethality phenomenology against TBMs is only realized because of our prior 30 years of strategic defense work. This has had a major impact on our thinking and weapon systems development and effectiveness for Theater (i.e., TBMs)

The threat in the year 2000 and beyond is different. Delivery systems will be low, slow, and stealthy. Payloads are likely to be chemical and/or biological. We have to initiate, immediately, a technology development master plan to address these new threats. Our technology "backlog" is almost depleted and not applicable in the out years.

TMD Lethality – Independent Assessment Study

- **Recommendation – Lethality:**

Reinvestment in our Technology Database

An Army technology development master plan must be formulated to address the new threat. Specific areas that require immediate attention:

- **In situ destruction of aerosol C/B clouds**
- **Improved database and modeling of live versus simulant agents (with and without stiffeners)**
- **Improved warhead designs to address the 100-percent SM kill problem**
- **A CM/UAV defense plan**
- **A passive defense plan**

TMD Lethality – Independent Assessment Study

- **Observations – Modeling:**

1. The PEELS code represents a top-level assessment of the engagement... but there exist serious concerns about:
   - SM "kill" modes/failure criteria/dispersion
   - Cloud formation and drift (atmospheric and meteorological physics)
   - Aerosolization (with and without stiffeners)
   - Empirical database
     - Vector state of intercept
     - SM dispersion
     - Interceptor warhead variances (HTK versus fragmentation)

TMD Lethality – Independent Assessment Study

- **Observations – Modeling (continued):**

2. The PEGEM code also represents a top-level assessment of the ground laydown, but does not address:
    - Live versus simulant agents (including stiffeners)
    - Casualty estimator module has limited modeling
        - Exposure routes (inhalation versus dermal and ingestion routes)
        - Population model (military versus general population)
        - Agent data (type survivability and persistence; no bio)

TMD Lethality – Independent Assessment Study

- **Recommendation – Modeling**

Prepare an *Army* modeling task force to address the inadequacies of the PEELS/PEGEM database. Special attention should be addressed to:

a. Aerosolization (with and without stiffeners)
b. SM failures/dispersion
c. Live versus simulant agents
d. Casualty estimator improvements (exposure routes, population model, agent model)
e. Collateral effects, including quarantine, medical treatment/casualty overloads, (military/civilian), crop/livestock/water contamination
f. Collateral effects on military operations resulting from "e" above

TMD Lethality – Independent Assessment Study

- **Observations – Passive Defense:**

1. There appears to be no appreciation and integrated effort within the community for the role passive defense and warning technologies can play in keeping casualty rates low

2. Virtually no TMD will be 100%; some of the SMs will survive

TMD Lethality – Independent Assessment Study

- **Recommendation – Passive Defense**

Prepare an Army master plan for C/B passive defense in Theater. This plan should address:

a. Likely, preemptive C/B strike against airports, seaports, and other forward staging areas
b. C/B strikes against civilian populations in Theater will likely disrupt military operations
c. Scenario gaming in which we perfect operational, contingency, and response (military, political, and human) alternatives
d. Technology development improvements for
   - C/B detection systems (BIDS)
   - Effective passive protection for soldiers
e. Recognition of the role of:
   - Pharmaceutical countermeasures (including vaccines)
   - Decontamination
   - Shelters

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- **Summary of recommendations (in order of priority)**

1. Development of an ***Army*** technology master plan
2. Development of an ***Army*** passive defense master plan
3. Development of an ***Army*** modeling task force

We believe the Army should set the standard by which the other services develop similar plans until eventually a joint, multiservice approach, plan, schedule, and budget are developed.

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Appendices

A. TOR Letter

B. Meeting Minutes (w/o attachments)

C. Telephone/Fax Numbers

D. Additional Source Material

D-1. Selected pages from 1993 Missile Defense Summer Study

D-2. Anthracis Spores in a Single Submunition

D-3. Bibliography

D-4. Glossary