KEYNOTE

27 April 1999

THINK GLOBALLY, ACT GLOBALLY

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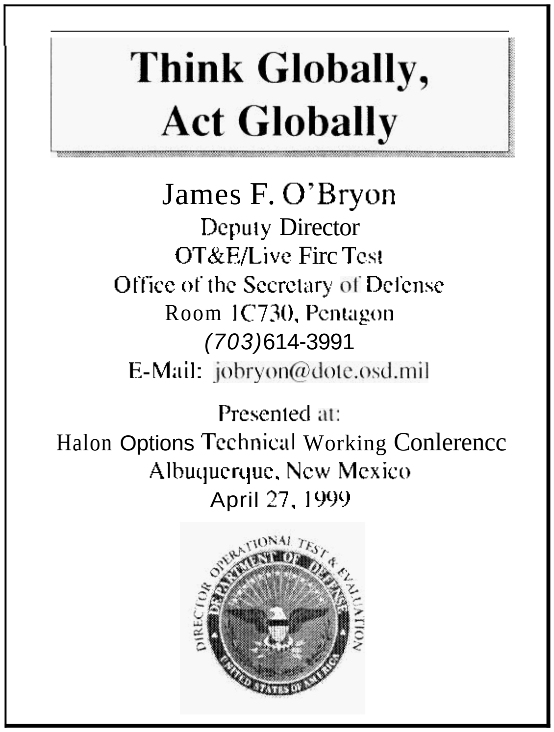
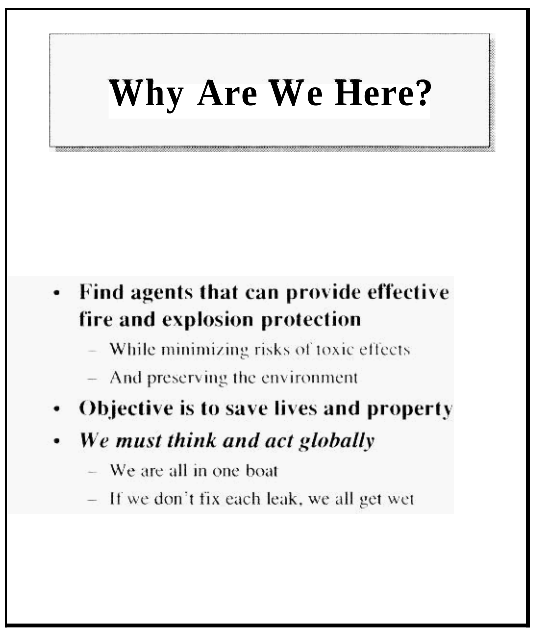
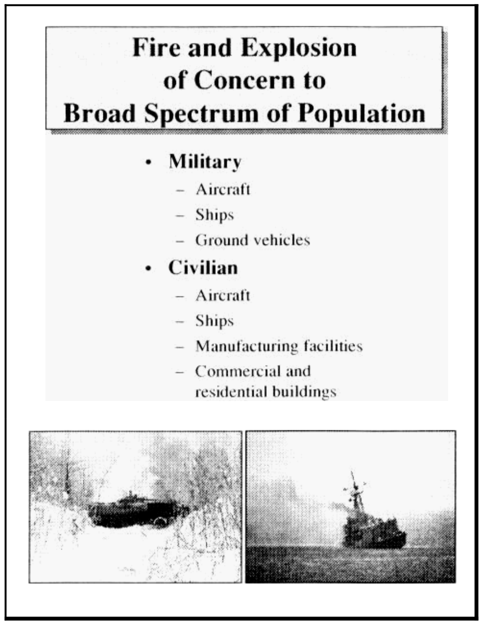




I am very happy to be here to address your conference on this very important subject. The depletion of the ozone layer, and now global warming concerns, are subjects that should be of interest to every person on the planet. If we don't **all** work together to solve these problems, both as individuals and as citizens of countries. we could eventually destroy our environment. What one country does or does not do to protect the environment affects every other country. Ozone depletion, in particular, has the potential to affect the well-being of the whole world. That is why we have to think globally and act globally. We must do our part to take care of the environment in a responsible manner.

We are here today to discuss one very important part of the problem, finding replacements for halon. **As** the person within the Office of the Secretary of Defense responsible to Congress for ensuring that our weapons systems are survivable and will protect their crews in a combat environment, I hold this subject near and dear to my heart. I am very concerned that we provide the user with adequate protection from fire and explosion, and that we also provide adequate protection to the user and maintenance personnel from accidental exposure to toxic agents.



Costs of USAF Aircraft Fires

- USAF estimated materiel costs for period 1966 to 1995 (in 1995 $)
  - Peacetime losses $9.3 B
  - Combat losses $5.9 B
  - Total Cost of Fires $15.2 B
- Costs do not include casualties
- Costs do not include other Services
- Cost of R&D during period--$0.3B (AF)
- Small investment, large potential return

Fire and explosion have been the largest causes of aircraft losses in combat. Peacetime fires also are a major problem. for both military and commercial aircraft. An Air Force study found that the cost of peacetime aircraft losses of Air Force aircraft due to fires, from 1966 to 1995, was *$9.3 billion* (in 1995 dollars). The cost of aircraft losses in combat due to fire and explosion during this same time period was *$5.9 billion.* This is a lot of money.

During that same time period, about $300 million was spent on research and development of fire and explosion suppression technologies—-a significant amount. hut only about 2% of the losses to fire during that period. The potential for saving lives and dollars is very significant.

Fire and Explosion Protection Examples for Aircraft

- Ullage fire and explosion protection
  - Foam on F/A-18, F-15, A-10, C-130
  - Halon on F-16
  - Nitrogen on C-5
  - On-Board Inert Gas Generator System on C-17, F-22, V-22, RAH-66*, H-1*, MH-47E*, MH-60K*
- Dry Bay Fire Protection
  - A-10, F/A-18, F-15, RAH-66*, V-22
- Engine Bay Fire Protection
  - On most multi-engine aircraft

* Planned

This potential to save lives and cquipment is the reason we spend ***a*** lot of time and effort to prevent fires and explosions in aircraft. For example, we have provided *ullage explosion protection* by using foam on the F/A- 18, halon on the F-16, and an onboard inert gas generating system (OBIGGS) on the C-17, F-22. and some helicopters. **We *also*** provide *dry bay protection* around fuel tanks on many aircraft where projectile and fragment impacts may ignite leaking fuel. For both safety and survivability reasons, we provide *engine bay fire protection* on most multi-engine aircraft.

We have similar fire concerns about ground vehicles and ships, and provide them fire protection in most cases. Many of the problems involved are similar, although the solutions may have to be different because of configuration differences. The TWA 800 experience showed that fuel tank ullage explosion is a problem for commercial aircraft as well as combat aircraft. Fire and explosion is a concern to a broad spectrum of military and commercial users, and we need to work together to solve the problems for the benefit of all.

Halon 1301 is a very effective fire-extinguishing agent. In fact, it works so well that there has not been a lot of scientific knowledge developed about why it is so effective, because there hasn't been an incentive to improve it. It worked, and that was all anybody needed to know in the past. Now that we are losing the use of halon and have to find a replacement, we are finding out how little we really understand about fire, and that finding a replacement for halon is a very difficult problem.

Dr. Reva Rubenstein from the EPA recently commented that the community once thought that a single, equally effective replacement for Halon 1301 would be found, and that some people are still thinking that way. Reva now believes that no single replacement agent or solution will be found, and that there should be a broader engineering approach to fire suppression that thinks through the problem, the installation, and the alternatives.

I agree with Reva. *There is no single answerfor all fire and explosion problems.* We are going to have to do smart engineering and provide designers a tool kit to help them do their job. Designers need to have good models and simulations to help them design fire suppression installations for our systems. Under our Safety and Survivability of Aircraft Initiative (SSAI), we are working this problem, as are others. Fire, much like weather, is an extremely complex physical phenomenon for which it is difficult to develop credible models. Dr. Lou Gritzo, from Sandia National Laboratories in conjunction with the Air Force Research Laboratory, is working this problem, and Lou will present the status of these efforts later this morning. As you will see, fire models and simulations are still a long way from being able to predict complex events. However. we have made a start and relatively coarse-grained knowledge of a few key parameters may be very useful in designing suppression systems.

The designer also needs good data on fire and explosion suppression agents, technologies, and design techniques. There are many people working these areas in both government and industry. The DoD Next Generation Fire Suppression Technology Program, or NGP, is addressing some of these problems. I am a member of the DoD Steering Committee that oversees this program. Dr. Richard Gann from NIST directs this program for the DoD. Dick will present a briefing on the NGP this afternoon and chair one of the two sessions that will present some of the projects that are underway. Dr. Robert Tapscott from the New Mexico Engineering Research Institute (NMERI) has been a major player in collecting and providing data in this area and serves, along with Dr. Rubenstein, in an important role as an honest broker in sorting through the claims and counter claims about various agents and systems. The Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS) sponsors developmental work in aircraft fire and explosion suppression technology. Some very innovative work on gas generators by several organizations has led to their use in dry bay protection applications on the F/A-18E/F and the **V-22.** *The V-22 application has already saved an aircraft in a safety-related ground* ***fire*** *incident.*

There are other efforts underway in all the services, the FAA, NASA, and within industry. The collective body of knowledge about fire and explosion is growing, and our understanding is improving. It is important that we continue to share these data and knowledge at conferences like this to accelerate the development of solutions to our problems.

Even if we eventually develop credible models and simulations. we will still have to do testing to determine the effectiveness of any particular design. Right now, testing is the only way to verify that the system works. We design a system based on the best experience and knowledge we have, and then test it to see if it works. If it doesn't work, we redesign the system, test it again, and iterate the design until it works. This can be **a** long and expensive process. We need credible, useful models and simulations to help the designer and to shorten this process. However, it should he understood that even a credible model and simulation is only a tool. and is never sufficient in itself to certify that a fire suppression system works correctly. We will always need realistic **tests** to certify that a system works **as** predicted. A major problem with certification is the need for repeatable fire tests that will allow us to compare agents and techniques in ***a*** valid way. Because fire is such a complex phenomenon and our understanding is limited. it is very difficult to conduct repeatable tests. We must develop repeatable fire test techniques for all types of equipment and applications. This is something that should be a high priority for everyone involved in this area.

I know that agent selection is an emotional subject to many people. There is no single solution and designers must look at each application and use fire protection technique that is most appropriate for that particular application. However. I would like to challenge each of you to take an objective look at a few related questions during this conference.

I am concerned that some agents may be prematurely eliminated from consideration by the way that cardiac sensitization evaluations are conducted. For example, adrenaline challenge testing puts the equivalent of 35 to 300% more adrenalinc in the body than it is physically possible for the body to produce. This extreme approach has eliminated some agents from consideration that probably should not have been eliminated. I ask you to look objectively at this test and whether it can be improved.

On Thursday afternoon, Dr. Allen Vinegar from the Air Force Research Laboratory is presenting ***an*** alternative approach to this test using modeling techniques that are being used by the EPA to evaluate safe exposures to halon replacement agents. Please take an objective look at this whole question.

The penalty for selecting agents with high safety or toxic risk is well recognized. The penalty of premature rejection of effective agents, however, may he overlooked. If an effective agent is rejected. we may not be able to find a suitable alternative to meet cost and weight constraints. and some areas may be left unprotected. Or, we may be forced to use a less effective agent and suffer greater losses from fires

One of the agents whose potential use has been clouded by the cardiac sensitization test is CF_3I. I am not an advocate of CF_3I per se. I am advocating that it, and any other agent, should receive a fair and objective evaluation based on its planned application. From information I have seen. it appears this agent may have some potential use in unoccupied areas. Why should it be totally eliminated from consideration, just because it might not be acceptable for certain other applications'!

Many of the halons we currently use are hazardous to some degree. We have developed ways to handle them safely and use them routinely. If we arc concerned about accidental discharge that could potentially harm a ground crew, then we can add switches that prevent accidental discharge on the ground. That does not seem "too hard" to me. I understand that the F-15 has never had an accidental release of halon on the ground. They must have solved the "switchology" problem; it seems others could do the same.

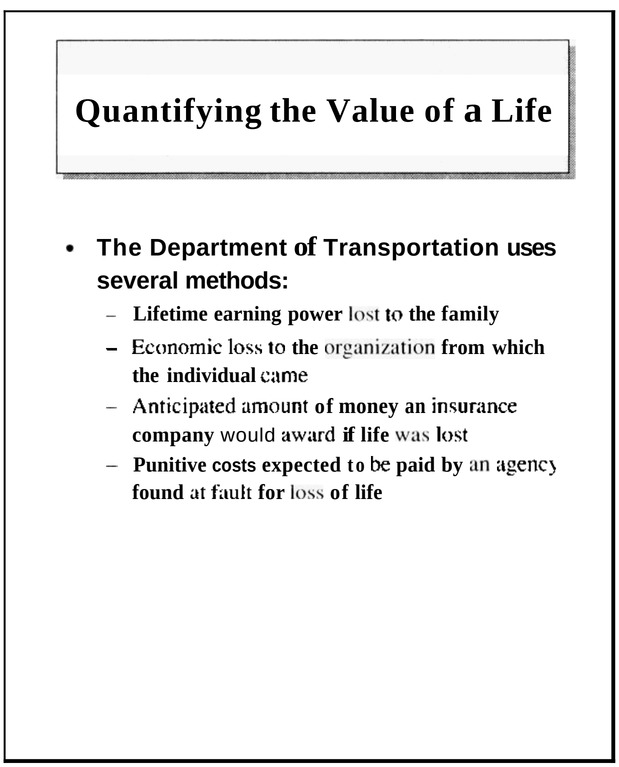
It would seem that the best way to approach this agent, and others like it, is to conduct a realistic and objective risk assessment. Look at everything in the total context of its use, assess the risk, and then determine where to use it or whether to use it at all. Most of us are scientists and engineers who are trained to think objectively and make decisions rationally. If we do that, I will be happy no matter what the answer is.

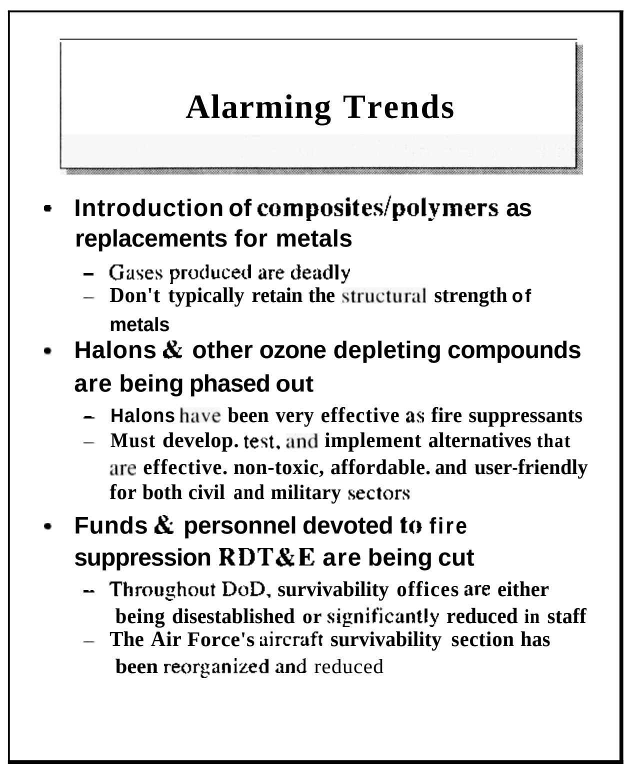
Another concern I have is that we seem to be depending too much on the Halon Bank, rather than aggressively pursuing, funding, and implementing alternative solutions. The EPA's responsible use policy allowed the DoD Halon Bank to be set up for critical uses. EPA's intent was that continued research would be carried out and that alternative solutions would be implemented as soon as they are found.

The Air Force F-16 currently uses halon to inert its fuel tank ullage. This halon system has been proven effective in ballistic tests conducted by the Air Force Research Laboratory's Aircraft Survivability Research Facility. If the F-16 is hit in combat, the halon should prevent fire and explosion in the ullage space of the fuel tank. However, every time the F-16 flies in harm's way and returns safely, it must dump **13** pounds of halon. There is an economical alternative available that would save halon, but we have not yet implemented it. The Halon Bank may be depleted sooner than expected if we continue to face conflicts such as those in Iraq and Kosovo.

In summary, fire and explosion suppression is a very important area. Saving lives and dollars and protecting the environment is the goal we are all trying to attain. We need to work together to accomplish this goal. I have challenged each of you to take a new look at certain areas during this conference, and I ask you to set aside any personal biases and look at these questions objectively. **As** we enter the new millennium. we have many challenges that we will have to face together. Let us use this conference to start facing them now.

Thank you for inviting me. Have a good and productive conference.





Keg Events in the Halon Replacement Movement

1987	Montreal Protocol established future production of halons at the 1987 production level
19x9	DoD Directive 6050.9 - Search for alternatives to CFCs and halons
1990	Clean Air Act Amendments limit U.S. production of Ozone Depleting Substances
1990	Fire Suppression Symposium at Aberdeen Proving Ground. MI)
1991	OSD LFT Office funded Halon Alternatives Research Committee (HARC) Secretarial and became Co-chair
1992	Copenhagen Amendments ban halon production for developing countries
1993	DoD directs new procurements will not require use of ozone depleting chemicals
1994	President decrees no production of halons

DoD Directive 6050.9 Requires That:

- DDRBE "...shall coordinate RBD programs. as appropriate, on alternative chemicals or technologies for fire and explosion suppression and, if necessary, other CFCs"
- DoD Components "...shall conduct RBD to identify or develop alternative processes, chemicals, or techniques for functions currently being met by CFCs and halons"

Army Statistics

- 127,000 tracked and wheeled vehicles in active Army
  - 100,000 light/medium and heavy wheeled systems in active Army
  - 27,000 tracked systems
- All need fire and explosion protection

Former Congressman
George Hochbrueckner, (D-NY)
November 4, 1998

Assessment of Halon Toxic Effects in Live Fire Testing

- Bradley LFT was first to include assessment of casualties from halon pyrolysis (Phase II, Oct '86-May '87)
- Toxic fumes were significant contributor to casualties
- Results were sensitive to assumptions about time to mask and/or evacuate

"More evidence is needed on likely crew response to slow developing fires and to the trauma of being hit ... for more realistic casualty ... assessments, and for the improvement of crew training." (OSD report on the Bradley LFT&E, 1987)

Some Inhalation Injury Sources

- "Smoke"
- Gases, fumes, vapors, aerosols, dusts
- Burning of plastics, foams, synthetic and natural fibers, and fire suppressants
- Cyanide, carbon monoxide. oxides of nitrogen, pyrolysis products, etc.

Inhalation Injury

- Toxicity of "smoke" inhalation is complex
- Brief exposure of high-level toxins causes significant health problems
- Army, Navy, Air Force, & Marine Corps have an interest in this critical issue
- Context of warfighters and the battlefield
- Fire in confined spaces

Why Is Fire Such an Issue for Live Fire Testing?

- It has been and continues to be a major source of combat casualties
- It has multiple effects
  - On People
    - Burns
    - Heat inhalation
    - Tonic fumes
  - On Equipment
    - Explosion of combustible liquids
    - Cook-off of military ordnance
    - Distortion of critical equipment
    - Crazing of optics/fire control
    - Soot/smoke cause failures in computers/commo gear

Halon Alternatives R&D Steering Group
Background

- Formed by ODDDRE(R&AT/ET) on September 3,1991
- Responds to DoD Policy Directive 6050.9
- Addresses the impact of
  - 1987 Montreal protocol on substances that deplete the ozone layer and
  - Title 6 of the U.S. Clean Air Act, 1990 Amendment

  on DoD's mission accomplishment capability

Dependence on Halon Bank

- We may he depending too **heavily** on using **Halon Bank** rather than aggressively pursuing alternatives
- Particular **concern** with systems which **dump halon** every combat sortie **even** when no fire event has occurred
  - F-16 about 13 lbs./sortie
  - F-117 about 30 lbs./sortie
- **Conflicts** such as Iraq and **Kosovo** may deplete hank sooner than anticipated
- We are continuing to release **ozone-**depleting chemicals
- There is **international** pressure **to** eliminate **Halon Bank**

Halon Use, Current Reserves

Reserve Average **Annual** Withdrawal Kate (**Based on** peace time rate5 + **Bosnia,** Iraq to **July 1998**)	**8,000" lbs**
AF "Ready to Issue" Reserves (As of July 31, 1998)	**800.000 lbs**
Un-reclaimed But Soon to be Included	**500,000 lbs**
Total Available To-date	**1,300,000 lbs**

* Can be orders of magnitude larger in conflicts such as Kosovo

Concerns

- **I'enalty for** selecting agents with high safety **or** toxic risk is well recognized
- **I'enalty for** premature **rejection of** effective agents is often **overlooked**
- **Some** agents may have been eliminated unnecessarily due **to**
  - Unrealistic testing
  - Irrelevant criteria
  - Personal biases
  - Lack of data
- **Rejecting** an effective agent based on an **over-estimate** of toxic risks may mean some areas go unprotected **or are** under-protected at the cost **of lives and** property

Fire Suppression Agents

- Considerable controversy **with** heated dehates over agent selection
- Selection **of** appropriate agents **lor various** applications **requires** rational, objective **evaluation of** benefits **vs risks**
  - Operational performance
  - Occupational safety/toxicity
  - Environmental safety
  - Costs

HFC-125 (Pentaflurorethane, CHF2CF3)

EPA Guidance

- If egress >1 minute, a concentration of 7.5% (NOAEL) shall not be exceeded
- If egress can be achieved between 30 seconds and 1 minute, a concentration of 10% (LOAEL) shall not be exceeded
- Concentrations > 10% shall only be used in unoccupied spaces

HFC-125 (Pentaflurorethane, CHF2CF3)

"In combat military situations. where crew spaces are closely adjacent to storage (unoccupied) spaces, and escape to a safe place is not always reasonable, all aspects of parent gas toxicity (along with the effects of HFC-125's breakdown products) is of high concern."

Adolph Januszkiewicz
Department of Respiratory Research
Walter Reed Army Institute of Research

HFC-125 (Pentaflurorethane, CHF2CF3)

- As a fire suppressant. HFC-125's engineering and environmental impacts seem workable
- HFC-125's effects on humans are not however perfect
- HFC-125 is expected to yield similar breakdown (pyrolysis) pruducts as other fluorocarbon alternatives
  - Hydrogen Fluoride (HF)
  - Carbonyl Fluoride (COF2)

Adolph Januszkiewicz
Department of Respiratory Research
Walter Reed Armv Institute of Research

CF3I Example

- Not an advocate but suggest an objective re-evaluation
- May have some potential uses especially in unoccupied spaces
- Many currently employed halons are hazardous to some degree
- CF3I may be more effective and no more haaardnus in some applications

EPA on CF31

- **EPS's** Significant Alternatives Program (SNAP) - "Any employee that could he in the area must be able **to** escape within 30 seconds. **The** employer shall assure that **no** unprotected employees enter the area during agent discharge."
- **In** military **applications,** escape may **not** always be achievable
- **Blending CF31** with other suppressants may have some potential
  - Toxic pyrolysis products must he considered
  - Full-scale tests will **help** estimate the **degree** to which **these** byproducts are produced
- lask is to search **for halon** alternatives that are **cost-effective** and safe for humans and the environment

Fire Suppressant Evaluation Parameters

- **Effectiveness/performance**
  - Good fire suppression
  - Good volumetric efficiency
  - Good stability/shelf life
- **Effects on humans**
  - Low acute toxicity
  - Low subchronic/chronic/developmental toxicity
  - Low toxicity of pyrolysis products
- **Environmental impact**
  - Low/no ozone depletion
  - Low/no global warming potential
  - Short atmospheric life time
- **Engineering aspects**
  - Reasonable material costs
  - Reasonable life cycle costs
  - Low corrosion
  - Clean
  - Storage bottle explosion risk
  - Low thermal/electrical conductivity

Criteria for Assessing Halon Fire Fighting Agents

- Class **A** effectiveness
- Class **B** effectiveness
- Class **C** effectiveness
- Class **D** effectiveness
- Complete volume **fill**
- Quick response **time/discharge** time
- **Persistence**
- Cooling effect
- **Throw/stream** character
- Agent health effects
- **Pyrolysis** health effects
- Visual acuity
- Environment of production
- Environment of agent
- Environment **of** pyrolysis

Criteria for Assessing Halon Fire Fighting Agents

- Cleanliness
- Electrical conductivity
- Agent compatibility
- Pyrolysis compatibility
- System compatibility
- Shelflife
- **Stability** in **bottle/climatic extremes/pressure** temperature
- Availability-pruduction
- **Refill** capability
- **Logistics/maintenance**
- 'lest hardware
- Cost
- Space and weight
- Valve

Criteria for Assessing Halon Fire Fighting Agents

- Discharge horn material
- Drop resistance
- Vibration
- Load factors
- Fragmentation resistance
- Corrosion resistance
- Leakage
- Instructions
- Operability

Toxicity and Testing Issues

- Pyrolysis products are affected by
  - Use of mixture of chemical
  - Chemicals with multiple elements
  - Materials fueling the fire (e.g., composites and munitions)
  - Temperature of the fire

Jury Is Still Out on Some Toxicity and Testing Issues

- Tier 1 - Acute/short term, mainly single exposure tests
  - Range finding tests to identify dose levels for longer term testing
  - Identification of toxic effects
  - General toxicity indicators
- Tier 2 - Subchronic or longer term multiple exposure
  - Developmental toxicity testing for possible birth defects or fetal toxicity
  - Reproduction studies - three generation studies
  - Ninety-day inhalation studies

Jury Is Still Out on Some Toxicity and Testing Issues

- Tier3
  - Second species developmental testing
  - Carcinogenicity studies
  - General toxicity indicatorys
- Possible additional testing
  - Metabolism testing
  - Ecological testing

Is Searching for Halon 1301 Alternatives

The Only Approach?

Situation Has Changed Greatly Since Halon Was First Implemented:

- Other Methods
- Affordable redundant computers and data backup systems
- Better ground fault detectors
- Faster circuit breakers
- Sealed electrical and electronic equipment
- Improvements in passive means to prevent and mitigate damage from explosions and fires

Is Searching for Halon 1301 Alternatives

- Improvements in other agents and delivery systems
  - Fine mists/sprays
  - Wafer additives
  - Carbon dioxide extinguishers
  - Multi-purpose powders

Some Halon 1301 Applications Were Probably Not the Right Choice:

- Hand-holds for open or windy areas
- Large, occupied engineering spaces on ships

President Can Order Production of Halon 1301 in an Emergency (Clean Air Act)

Is Searching for Halon 1301 Alternatives

There Is Probably More than Enough Halon 1301 in Nun-Essential Applications and in Reserves to Bridge until Production Could He Resumed in an Emergency

Representative Halon 1301 Uses

- Mission criticallessential
  - Combat ground vehicle crew compartment
  - Aircraft engine nacelle
  - Dry bay ballistic protection
  - Fuel tank explosion protection
- Non-Essential
  - Electrical equipment spaces
  - Computer rooms
  - Large occupied engineering spaces on Navy ships
  - Hand-held Halon 1301 extinguishers in open or breezy areas

Toxicity and Testing Issues

- **Numerous possible exposure scenarios**
  - Personnel in explosion suppression
  - Personnel involved in continual manufacturing. testing. and training operations and handling and filling tanks
  - Accidental discharges

- **Routes of exposure**
  - Inhalation
  - Eyes
  - Ski“
  - Oral
  - Dermal

Safe Employment

- Develop ways to handle and use agents safely
- Preventing accidental discharge is significant issue
- “Switchology” to limit risk of accidental discharge through clever design of safety features such as:
  - Switch to disable system when maintenance door is opened
  - Remove - before - flight pin
- Experience
  - F/A-18 has had about *50* accidental discharges per year
  - F-IS has safety switches and has never had an accidental discharge of halon on the pround

Some Current Efforts

- **Next Generation Fire Suppression Technology Program (NGP)**
- **JTCG/AS**
- **JLF**
- **Services**
- **NASA**
- **FAA**
- **NIST**
- **SSAI**
- **ASCI**
- **TILV**

HALON Replacement

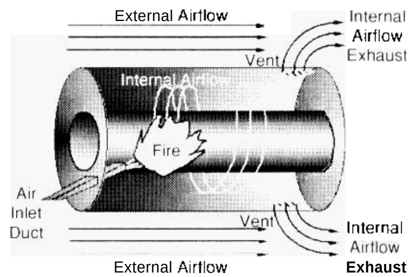
- It appears no one agent or method will be best for all applications
- Broader thinking and smart engineering are required
- Designers need a tool kit
  - Models and simulations
  - Data on agents, technologies, and techniques
  - Repeatable comparison tests

Other Live Fire Testing Initiatives Usable By The Private Sector

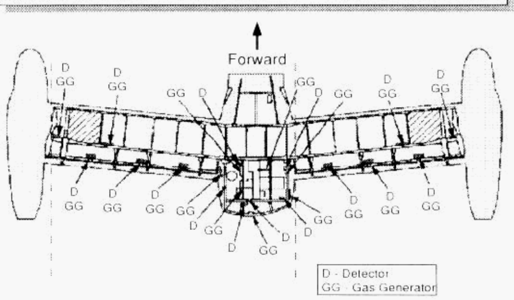
- Modeling and simulation/testing of fire initiation and fire suppression
- MOA with Department of Energy to piggyback Live Fire Testing against aircraft, tanks, and ships to collect data for model construction and validation
- Support to the Survivability/Vulnerability Information Analysis Center (SURVIAC)
- Assessment of shock trauma injury data from industry, private sector due to blunt trauma, burns, to generate multi-injury methodology for casualty prediction (ORCA)

Need for Testing and Modeling

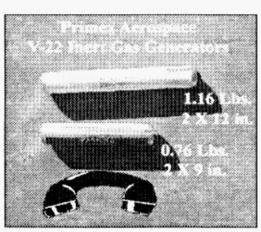
- We iterate between design and test until system works adequately
- Models needed to reduce iterations
- We will still need realistic tests to verify performance
- We need repeatable test techniques for all types of equipment and applications



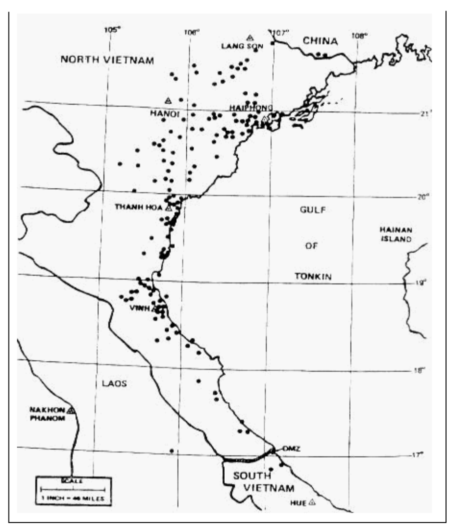
Fire Detectors and Gas Generators in V-22



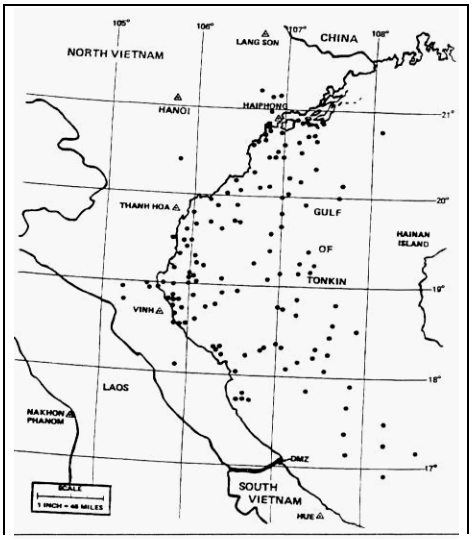
V-22 Suppression System has already saved an aircraft in a safety related ground fire incident.



Known Ejection Locations of Navy Aircrewmen Who Became POWs during the S.E.A. Conflict

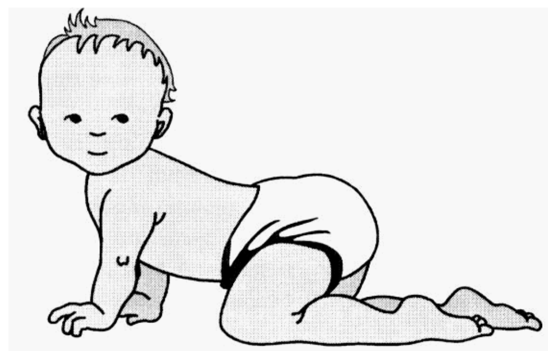


Locations of Navy Rescues of Navy Aircrewmen During the Southeast Asia Conflict



Change

The only one who likes change is a wet baby.



Summary

- **Goal is to save lives and property while protecting the environment**
- **We need to think and act globally to meet the goal**
- **We need to re-evaluate agents**
- **We need to end dependence on Halon Bank**
- **Please contact us, we want to work with you:**

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