

# CONTINUOUSLY CHANGING RANKING OF HALON ALTERNATIVES

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**Continuously Changing Ranking of HALON Alternatives**

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The results presented here were generated by Internal Research And Development (IRAD) funds of The Boeing Company and the heritage McDonnell Douglas Corporation in cooperation with several government agencies and fire extinguishing equipment suppliers.

**All** aircraft types have some form of fire protection, detection, and/or hardening and essentially all are considering using HALON alternative technologies for future production and/or retrofit applications.

**I** want to discuss my view of the rapidly changing perception/assessment of fire protection technologies, how and why the ranking of these HALON alternative technologies have rapidly changed over the last several years, and my view of the current state of the art for aircraft applications.

# Background

- **Objective:**
  - Replace All On-Board ‘HALON’ Fire Protection Systems With ‘Environmentally Friendly’ Alternatives
  
- **Applications:**

<ul style="list-style-type: none"><li>- Engine Nacelles</li><li>- Passenger / Crew</li><li>- Lavatories</li></ul>	<ul style="list-style-type: none"><li>- Cargo Bays</li><li>- Dry Bays</li><li>- Fuel Tanks</li></ul>
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- **Strategy:**

<ul style="list-style-type: none"><li>- Short Term:</li><li>- Mid-Far Term:</li><li>- Prepare for Eventual Loss of Stockpile</li></ul>	<ul style="list-style-type: none"><li>Rely on HALON Stockpiles</li><li>“Timely” Transition</li></ul>
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The industry goal is to replace all HALON fire/explosion protection on all new aircraft for all applications, and ultimately retrofit older aircraft when the appropriate technology is economically and politically viable.

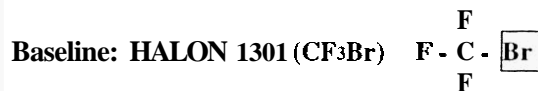
Multi-engine Helicopters, Transports, and Fighter/Attack aircraft require engine nacelle/APU/Gearbox protection.

Commercial aircraft protect all of the applications except for Dry Bay fires and Fuel ~~Tank~~ fire and explosions. The industry and government regulators have been and are still considering whether or not fuel tanks need protection.

Combat aircraft generally protect engine nacelles on multi-engine aircraft and many also protect the fuel tanks and/or dry bays

We need to rely on HALON banks in the near term, thus we need to insure that HALON stocks are preserved, then transition to “Green” technologies at the appropriate time.

## Leading 1301 Alternatives



**Solid Propellant Gas Generators:**    N<sub>2</sub>, CO<sub>2</sub>, H<sub>2</sub>O, "Dust"

**Dry Chemical: (NaHCO<sub>3</sub>) Sodium Bicarbonate + "Flow Enhancer"**

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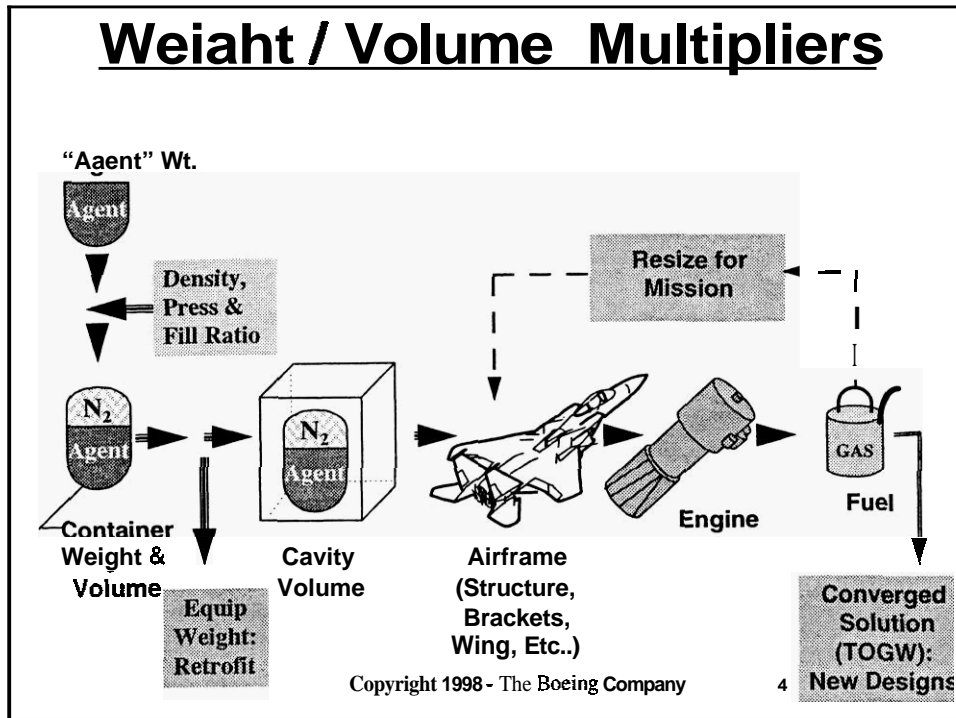
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The leading near term alternatives to HALON 1301 are listed with the significant differences highlighted.

Dry chemicals are also shown because of recent interest, however clean-up and corrosion concerns due to false discharge have made this approach difficult for many to accept. **F/A** aircraft engines may cost a few million dollars each and **the clean up** costs could be substantial for false discharge. The aircraft structure is also of concern.

Few of these alternatives could be accepted for any specific **F/A** application without additional work.

# Weight / Volume Multipliers



Some of the non-HALON alternatives require more weight and volume of agent than HALON 1301. To assess the impact of these technologies we utilized a “rubber” aircraft sizing approach based on the historical weight volume sensitivities developed in sizing and evaluation various historical aircraft designs.

Additional “agent” requires additional volume and weight for the “agent”, bottle, brackets, etc.

The larger bottle requires more volume and there is a volume packing inefficiency which must be applied to create the additional cavity volume required for the bottle.

Additional airframe structure is required to carry the extra weight and cavity volume.

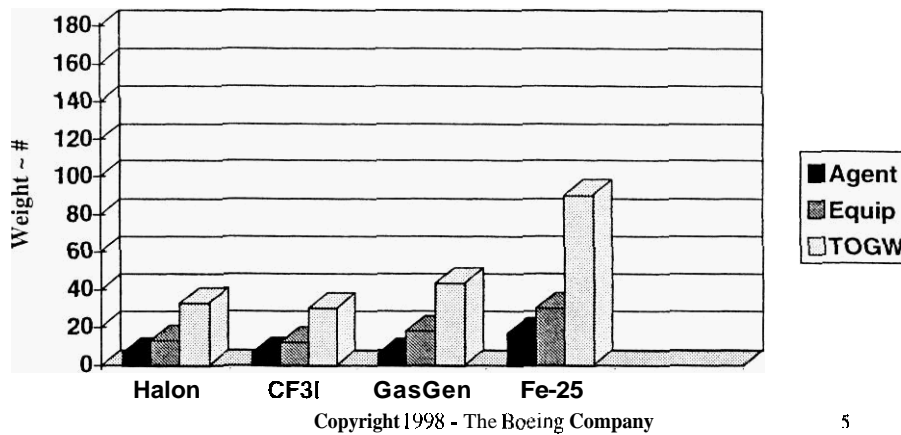
Larger engines are required to provide the same performance with the extra weight and drag.

More fuel is required by the larger engine to obtain the same range.

The structure and engine must get larger to carry the additional fuel.

Continues to iterate until the solution converges.

## Representative F/A Engine Bay Protection Penalties - 1995



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This evaluation compares HALON 1301 against the leading alternatives considered at that time. CF3I indicated no penalty, gas generators indicated little penalty and **HFC-125** (Fe-25) indicated heavy penalty.

Based on this assessment, Boeing Phantom Works (then McDonnell Douglas) R&D primarily concentrated on gas generators, with USN “encouragement”, and CF3I, although we continued limited activity with the other technologies.

Note: TOGW = Take Off Gross Weight and was determined by the process illustrated in the previous chart.

(1301)

F  
F-C-Br  
F

## HFC-125 (Fe-25)

(HFC-125)

F F  
F-C-C-H  
F F

- **Initial Belief: Require 2-3 Times HALON 1301 Qty.**
- **More Than 1000 Test Fires @ Dayton (WL/FIVS)**
- **Large Data Base**
  - **Least Development Cost ??**
- **Weight Competitive Data Now Available (USAF, USSR)**
  - **Improved Distribution**
  - **Selected for F-22, V-22, and considered for F/A-18 E/F**

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HFC-125(Fe-25) was originally thought to require 2-3 times the quantity of material as HALON 1301, therefore there was little serious consideration given to this material, especially in the F/A community since volume is so critical and we were looking for both a production and retrofit candidate.

There is a large data base for Fe-25 and the design equations have been released. Based on our preliminary understanding of these equations, the large volume **and** weight penalties shown by earlier studies may be unduly pessimistic. Combining the data from these equations with an increasing data base from tests with improved distribution systems make this alternative much more attractive than previously thought. Although not a "drop-in" replacement, it may now be much more competitive.

We are continuing to concentrate our efforts on this material.

## Gas Generators

- **Potential Weight/Volume Equivalent to HALON**
- **Very Efficient Storage of Inert Gas**
- **Automotive Technology with 20-25 Year Life ??**
- **“Hot” Exhaust Gas Issue**
  - **New Distribution Lines, Insulation, etc.**
  - **Redesign Required**
- **First Generation - Larger, Heavier, More Costly than Expected**
- **Second Generation Improving**
- **High cost for handling and qualifying pyrotechnics**
- **Scheduled Replacement Interval (-5 Yr) has Heavy Impact**

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The high density storage of inert gases in the solid propellant made this concept very attractive in early evaluations.

Several series of tests verified that fires could be successfully extinguished with gas generators and reignition could be prevented. Early testing also indicated that the weight of the solid propellant charge required to extinguish the flame could be approximately the same as the weight of HALON 1301 used in current systems.

As first generation gas generators matured and more information accumulated about the impact of the larger gas generators, assessments began to change. Live fire testing has been disappointing as have the system weights and volumes because of the difficult integration issues associated with “Hot” exhaust gases and “Hot” equipment, persistent inerting to prevent reignition, etc. Fires are successfully extinguished, but the integration penalties (weight, volume, and cost) are much higher than expected and relight is sometimes an issue.

Second and Third generation generators are expected to show significant improvements, but Life Cycle Cost (LCC) may still be a problem because of the requirement to replace all pyrotechnic devices periodically (usually at 3-5 year intervals) and the high development cost of qualifying explosives.

<b>(1301)</b> <b>F</b> <b>F-C-Br</b> <b>F</b>	<b>CF<sub>3</sub>I</b>	<b>(CF3I)</b> <b>F</b> <b>F-C-I</b> <b>F</b>
<ul style="list-style-type: none"> <li>• <b>Approx. HALON Effectiveness (Potential “Drop- In”)</b></li> <li>• <b>Low Temp Concerns (-9F Boiling Pt vs -70F for 1301)</b> <ul style="list-style-type: none"> <li>- <b>Limited “Room” Data Promising</b></li> </ul> </li> <li>• <b>Toxicity Related Concerns</b> <ul style="list-style-type: none"> <li>- <b>Cardiac Sensitivity in Dogs (0.4% LOAEL)</b></li> <li>- <b>Similar to HALON 1211 (1.0% LOAEL)</b></li> <li>- <b>HALON 1011 &amp; 1202 Appeared More Toxic in Rats</b></li> <li>- <b>Toxicity of combustion products ?</b></li> </ul> </li> <li>• <b>Little Support for Additional Work</b></li> <li>• <b>Technical / Political “Hard Sell”</b></li> <li>• <b>Comprehensive Hazard Evaluation Needed</b></li> </ul>		
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CF3I has an efficacy similar to HALON 1301 at ambient temperatures and was initially thought to be a near “drop-in” replacement alternative.

Two major issues have limited it’s acceptance;

- a) Concerns about cold weather performance
- b) Concerns about cardiac sensitization

Although CF3I is still the technology with the least weight and volume penalties, it is still the most difficult technical and political “sell”.

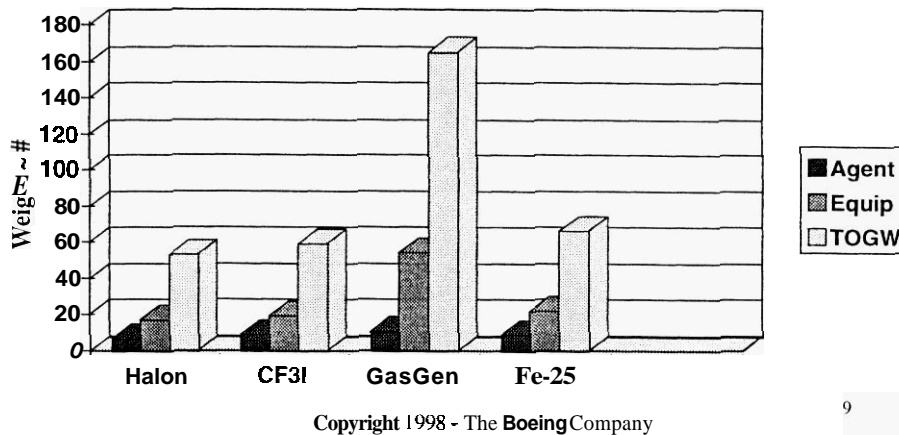
Acceptance of this technology for land based aircraft will be much easier than for carrier based aircraft because of the possible risk to crew members quartered below the hangar deck. Another concern is the presence of free Iodine in closed areas following a fire.

We **are** continuing a low level effort to determine if acceptable “safety” procedures and/or designs could be utilized to address the toxicity related concerns on land based tactical aircraft.

There is little support for additional work with CF3I or the comprehensive hazard assessment for all alternate technologies and related chemicals.



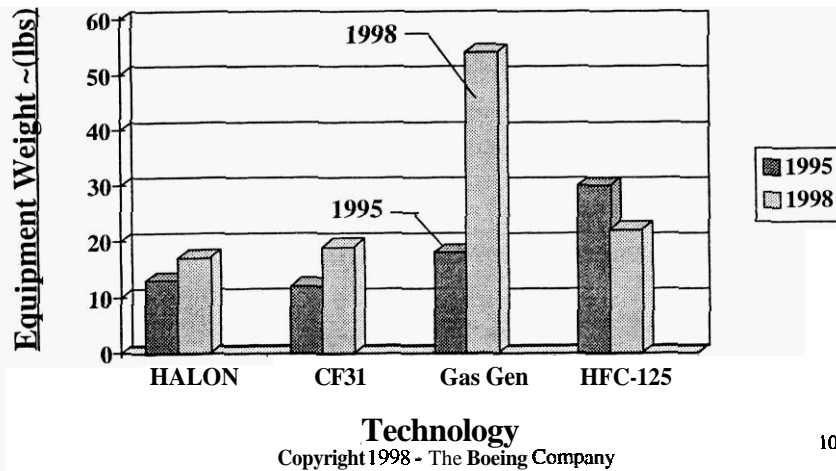
## Representative F/A Engine Bay Protection Penalties - 1998



Assessments made last year that accounted for the latest information available for maturing gas generator technologies (first generation) and evolving R&D data on HCF-125 testing with refined distribution systems indicate a radically different ranking of the technologies than those obtained in 1995.

The high temperatures associated with the larger, longer burning Gas Generator is the principal cause of the weight penalty.

## 1995 to 1998 F/A Comparison



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This chart was prepared to clarify the changes in assessing the weight penalties for the leading alternatives between the earlier (1995) and current (1998) rankings.

When the assessments were refined to reflect the current knowledge base, first generation gas generators were not nearly as attractive. In addition, the high LCC issue associated with periodic replacement also makes them unattractive.

The HALON weight increase reflects refinements in the 1998 assessment process which is reflected in all the technologies assessed in 1998.

The CF3I weight also increased because we now assume use of the HALON sized container.

The Gas Generator increase is primarily due to the design changes needed to address the hot exhaust gas issues.

The evolving data on HFC-125 with refined distribution systems have reduced the weight impact and now make it much more competitive without the LCC impact of the gas generators.

## Other Alternatives

- **Advanced Gas Generators With**
  - **Lower Temperatures**
  - **More Efficient Gas Generation**
  - **“Active” Components**
- **“Water” Mist (Water “+??”)**
- **Hybrids**
- **Several Candidates Have Had Little Aerospace Acceptance**
  - **Powders, Aerosols, Gels, etc.**
    - **Clean-up, Corrosion ??**
- **PBr3**

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Each of the above alternatives has been mentioned for aircraft applications and periodically someone suggests some variant of these technologies. Sometime one of these may look attractive, but up to now most are perceived to be too immature and/or have some serious limitation.

Hybrids retain the LCC penalties of gas generators, Advanced agents are not yet mature enough to consider, and “Water” Mist has not yet demonstrated adequate low temperature performance (The freezing issue may require additives that make the “Water” = Water + ?? ). Many of the others are perceived to pose “clean-up”, material compatibility, and/or human hazard issues that must be addressed before they are likely to receive serious consideration.