NEXT-GENERATION FIRE SUPPRESSION TECHNOLOGY PROGRAM

Richard G. Gann
NGP Technical Program Manager
and
Chief, Fire Science Division
Building and Fire Research Laboratory
National Institute of Standards and Technology
Gaithersburg, MD 20899 USA

ABSTRACT

The Next-Generation Fire Suppression Technology Program (NGP), now in its second year, has as its goal the development by 2004 of alternative fire fighting technologies to Halon 1301 that can be economically implemented in aircraft, ships, land combat vehicles, and critical mission support facilities. This paper describes the first projects and their early results.

BACKGROUND

In FY1997, the Department of Defense (DoD) initiated the NGP, an 8-year, $46M research program to develop new fire suppression technologies for the replacement of Halon 1301 in weapon systems. Halon 1301 (CF_3Br) has long been the choice for fire extinguishment in most weapon systems and mission-critical facilities. However, due to its high ozone-depletion potential, Halon 1301 was banned from production as of 1 January 1994, under the Copenhagen Amendments to the Montreal Protocol on Substances that Deplete the Ozone Layer.

The NGP is a logical extension of the on-going DoD activities under the Technology Development Plan (TDP) for Alternatives to Ozone-Depleting Substances for Weapon System Use. TDP efforts had identified viable, near-term halon alternatives for a wide variety of weapon system applications. These alternatives typically require weights and volumes that are double or triple those of Halon 1301 for equivalent effectiveness. While they can be readily accommodated in new system designs, they pose a significant problem to existing weapon systems because of form, fit, and function constraints. Given the current extensions of in-service lives of fielded weapon systems, this problem could ultimately require DoD program managers to expend large amounts of funding and time for fire suppression system redesign and reconfiguration.

The goal of the NGP is to develop and demonstrate, by 2004, retrofitable, economically feasible, environmentally acceptable and user-safe processes, techniques, and fluids that meet the operational requirements currently satisfied by Halon 1301 systems in aircraft, ships, land combat vehicles, and critical mission support facilities. The results are to be specifically applicable to fielded weapons systems. If successful, the NGP could eliminate DoD dependence on a substance no longer in national production, minimize any readiness impacts that could result if Halon 1301 use restrictions were imposed in the future, and achieve these at greatly reduced cost. The potential fire locations for which alternatives to Halon 1301 are sought include aircraft engine nacelles, dry bays, cargo bays, and fuel tanks; ground vehicle crew compartments; and shipboard machinery spaces and storage compartments (Figure 1). These locations vary in size, shape, and occupancy; the fuels are solids, vapors, and liquids (pools and sprays); and the

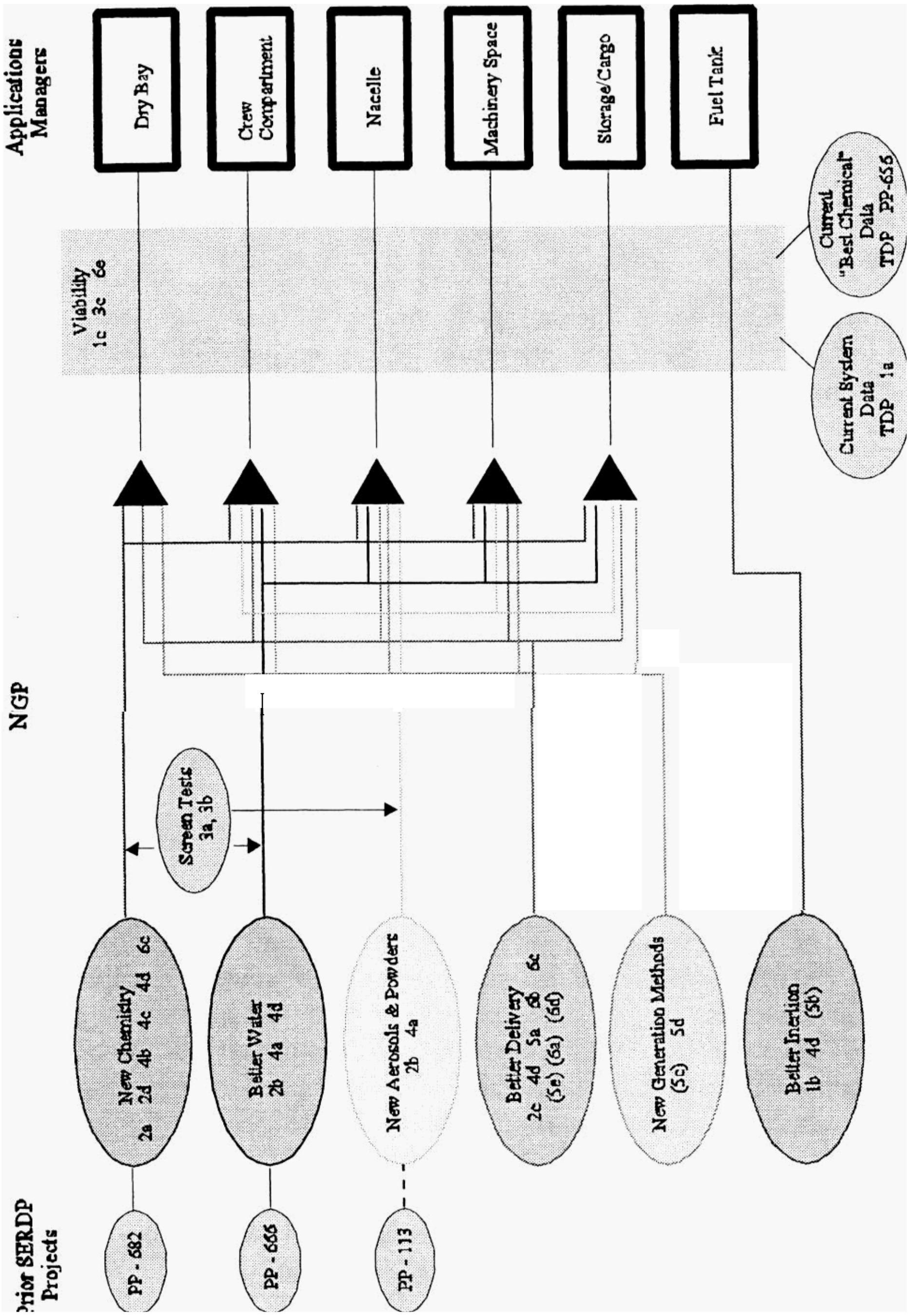

Figure 1. DoD Research for Environmentally Suitable Fire Suppression Technologies.

suppression times range from about 0.01 to 100 sec. The hazards to be avoided include harm to people, thermal damage, post-fire corrosion, loss of visibility, and overpressure. Successful candidates must thus do well in the following: fire suppression efficiency and reignition quenching, **ODP, GWP,** atmospheric lifetime, suppressant residue level, electrical conductivity, metals non-corrosivity and polymeric materials compatibility, long-term storage stability, low toxicity of the chemical and its combustion and decomposition products, speed of dispersion, and safety and occupational health requirements. To be cost-effective, the suppressant and storage/delivery system must be of light weight and low volume, as well as compatible with the host designs of existing platforms.

Information on the strategy of the **NGP** can be found at the Defense Research and Engineering website: www.dtic.mil/ddre/fire_suppression/.

CURRENT PROJECTS

The **NGP** is now in its second year of operation. Ten projects began in FY97, six of which are continuing into FY98. Fifteen additional projects were initiated recently in FY98. While the overall effort can be described in different ways, at this early stage of the **NGP,** it appears most informative to **use** the following structure. The distribution of effort is shown in Figure 2. The full progress reports will soon be available at the **NGP** website: www.dtic.mil/ngp/.

DATA ON CURRENT FIRES AND SUPPRESSION SYSTEMS

(1) **Development of Model Fires for Fire Suppression Research—PI:** Anthony Finnerty, ARL; Associate Investigators: James Tucker, AFRL and Juan Vitali, ARA, Ronald Sheinson, **NRL**

Objectives: To characterize the types of fires on which the Military uses Halon 1301 in ground vehicles, aircraft, and ships; to tabulate the spatial and operational constraints of current Halon 1301 systems to serve as guidance for the appropriateness of retrofit fire suppression technologies.

Status: A report is in draft, characterizing Halon 1301 fire suppression systems in representative current combat platforms and the type of fires on which these halon systems are used.

VIABILITY OF NEW FIRE SUPPRESSION TECHNOLOGIES

(1) **Relative Benefit Assessment of Fire Protection System Changes—PI:** Dennis Weiland, **AFRL**

Objectives: To develop a methodology that will quantify a technology by its cost in order to determine if it is sufficiently superior to the state of the **art** to warrant further pursuit; to provide a groundwork for a future, more comprehensive model to be used by weapons program managers for determining, via life cycle costs, the most appropriate alternative to use to replace Halon 1301 in their systems; and to use the developed methodology to identify the aspects of fire protection

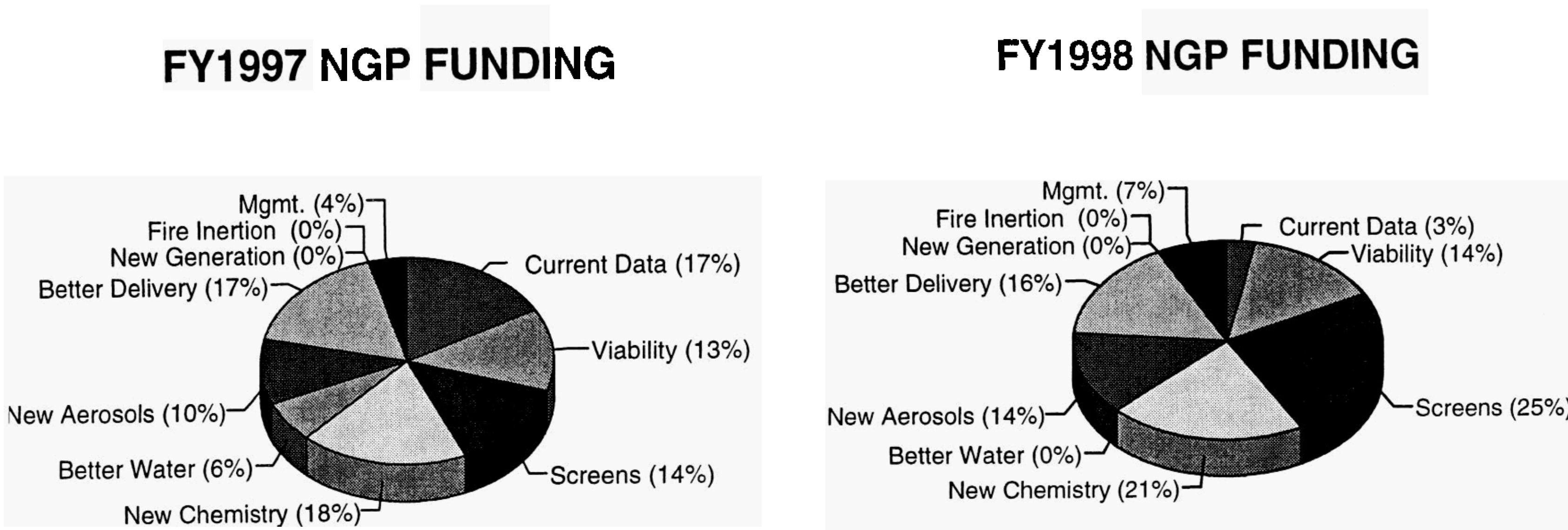

Figure 2. Fraction of Funding by Technical Approach.

technologies that offer the highest potential payoffs. This knowledge can be fed back into the NGP for immediate exploitation.

Status: New project

(2) Laser-based Instrumentation for Real-time, In-situ Measurements of Combustible Gases, Combustion By-products, and Suppressant Concentrations—PI Kevin McNesby, **ARL**

Objectives: To develop and demonstrate/validate new laser-based instrumentation for the measurement of concentrations of candidate suppressants, oxygen, fuels, and combustion byproducts during suppression of flames and explosions; and to measure gas production and distribution during suppression of deflagrations in crew and engine compartments of a ground vehicle.

Status: **A** test rig has been installed in a Bradley fighting vehicle for measurement of HF gas using NIR-TDL absorption spectroscopy, FT-IR spectroscopy and using a fluoride ion selective electrode. In-situ, real-time measurement of HF during suppression of **JP-8** fuel fires demonstrated the effectiveness of HF scavenging agents when added to fluorocarbon-based suppressants. NIR-TDL absorption spectroscopy was also used to measure O_2 during suppression of fires in the crew compartment. Laser-induced breakdown spectroscopy is being developed for detection of both flame suppressants and some combustion products.

(3) Fast Response Species Characterization During Flame Suppression—PI: George Mulholland, NIST

Objective: To develop new instrumentation for measuring agent concentration during a release with a 10 ms time response, fast enough to follow the fastest fires experienced in current weapons systems.

Status: New project.

SUPPRESSANT SCREENING TESTS

(1) Dispersed Liquid Agent Fire Suppression Screen—PI: Jiann C. Yang, NIST

Objective: To develop a bench-scale suppression screen (or multiple screens) for comparing the flame extinction performance of dispersed gases and liquids.

Status: **A** flow facility and modified, propane-air Tsuji-type burner have been developed for routine determination of the flame suppression effectiveness of both gaseous and aerosol suppressants. Extinction is defined as when blow-off (an abrupt transition from a stable enveloped flame to a wake flame) occurs. The performances of the burner and the flow facility have been characterized and calibrated using gaseous suppressants. The performance of several prototype droplet generators is currently being evaluated using water droplets.

(2) Suppression System Effectiveness Screening—PI William Grosshandler, NIST

Objectives: To design and construct a well-characterized bench-scale suppression screen for measuring the effectiveness of gaseous agents and dispersed fluid mists in suppressing and preventing re-ignition of a turbulent, obstructed flame burning either gaseous or condensed fuels; to evaluate the impact of transient agent delivery on flame extinguishment; and to screen the effects of agents on condensed (solid and liquid) fuel surfaces.

Status: New project

(3) Toxicological Assessment of Human Health Consequences Associated with Inhalation of Halon Replacement Chemicals–PI: Gary Jepson, AFRL

Objectives: To provide a defensible approach and appropriate tools for decision makers, tasked with balancing performance and personnel safety issues; and to evaluate the acute toxicity potential of inhaled fire suppressants.

Status: New project

(4) Agent Compatibility with People, Materials and the Environment—PIS: Marc Nyden, NIST, and Stephanie Skaggs, Universal Technical Services

Objectives: To identify and document the best available screening methods for the toxicity, environ-mental impact, and materials compatibility of new suppressants and their fire degradation products; and to identify those screening methods needing further development to meet the needs of the NGP.

Status: A workshop of experts in these fields was held 14-15 November 1997. The unanimous agreement was that there are no research areas, other than those already being pursued, that required new efforts in FY 1999. A report on the screens to be used is being prepared.

(5) Environmental Impact of New Chemical Agents for Fire Suppression—PIS: Robert Huie, NIST, and Andrzej Miziolek, **ARL**

Objective: To evaluate candidate agents from new chemical families in order to establish their environmental impact and behavior during storage.

Status: New project

NEW FLAME SUPPRESSION CHEMISTRY

(1) Mechanisms of Ultra-high Efficiency Chemical Suppressants—PIs: Kevin McNesby, ARL and James Fleming, **NRL**

Objectives: To determine how chemicals that are as or more efficient than Halon 1301 (CF_3Br) quench the various flames **of** military interest; using iron pentacarbonyl **as** the prototype "superagent" fire suppressant, to understand key chemical reactions **or** processes of combustion that are affected by "superagent" suppressants and how these reactions or processes differ from those important for fire suppression by Halon 1301; to determine minimum properties for a "superagent" suppressant; to identify other candidate high-efficiency chemical fire suppression agents as candidates for replacing Halon 1301.

Status: **A** comprehensive literature survey has been completed of flame inhibition and flame suppression data on "superagents," chemicals that are at least as effective as Halon 1301. Low-pressure, opposed flow, methane/air diffusion flames, both unperturbed and with the addition of CF_3Br and $Fe(CO)_5$ were characterized. The flame character and extinction concentration for $Fe(CO)_5$ added to the oxidizer side were determined. The capability to measure visible emission, infrared, and OH spectra were added. Changes in C_2 and CH_2 radicals upon addition of $Fe(CO)_5$ to the oxidizer stream were measured. The size, composition, and infrared reflectance spectroscopy of particulates formed during inhibition of low pressure methane/air flames inhibited by $Fe(CO)_5$ were measured.

(2) Identification and **Proof** Testing **of** New Total Flooding Agents — PI Robert E Tapscott, NMERI

Objectives: To identify and develop performance data for best compounds from among the following classes: phosphorous nitrides, silanes, siloxanes, and perhaps fluorinated amines and/or ethers; and to determine which types of these chemicals are the best candidates for further study.

Status: This project has been completed. A detailed examination has been performed of the ODP, GWP, and toxicity estimates and the development of synthetic procedures for a range of silicon and phosphorus compounds, fluorinated amines, and fluorinated ethers. A number of these appear to have potentially acceptable fire suppression, toxicity, and environmental properties.

(3) Flame Inhibition by Phosphorus-containing Compounds — PI Elizabeth M. Fisher, Cornell University

Objectives: To identify and evaluate the flame extinction performance and toxicity of highly effective, low-ODP and low-GWP phosphorus-containing fire suppressants that could be used as total flooding agents.

Status: **A** novel method for approaching extinction was devised for low vapor-pressure additives. Dimethyl methylphosphonate and trimethyl phosphate were found to be **2-4** times as effective as CF_3Br as a flame suppressant in propane/air diffusion flames. A literature search shows that some PCCs likely to have low environmental impact and low toxicity.

(4) Tropodegradable Bromocarbon Extinguishants — PI: J. Douglas Mather, NMERI

Objectives: To identify, synthesize, and test the flame extinguishment capability of organobromine compounds with estimated acceptably low toxicity, ODP, and GWP, which could be used as flooding agents.

Status: New project

(5) Main Group Compounds as Extinguishants — PI: J. Douglas Mather, NMERI

Objectives: To determine whether there are compounds based on the chemistries of sulfur, silicon, boron, etc., that are suitable for fire suppression; and, if so, to identify promising candidates for full characterization.

Status: New project

(6) Super-effective Thermal **Suppressants**—PI: William Pitts, NIST

Objectives: To assess whether or not thermal fire extinguishing agents comparable in efficiency to Halon 1301 are feasible; and, if so, to provide a list of the best potential candidates and their properties along with recommendations for additional testing.
Status: New project

BETTER USE OF WATER

(1) Suppression Effectiveness of Aerosols and Particles — PI Ronald Sheinson, NRL

Objectives: To quantify the effect of aerosol properties on the efficiency of gas-phase flame suppression and develop a list of liquids and solids manifesting desirable values of these properties.

Status: A powder delivery system was designed and integrated into a counterflow diffusion flame (CFDF) burner assembly. Extinction concentrations for propane/air flames were determined for potassium bicarbonate, sodium bicarbonate, and potassium bicarbonate, each sized from $<$ 38 mm to $>$ 90 mm. Potassium (vs. sodium) and smaller particle size yielded higher efficiency. Particle sizes diminished as particles penetrated the flames. Aerosol momentum is also a key factor for suppression effectiveness, especially if the aerosol and air velocities differ.

(2) Droplet Interactions with Hot Surfaces — PI Yudaya Sivathanu, En'Urga, Inc.

Objectives: To obtain the data and understanding of interactions with burning surfaces required to engineer improved heterogeneous agent dispersion systems with enhanced fire-extinction capability.

Status: New project

(3) Technical Support for the Study of Droplet Interactions with Hot Surfaces — PI: Jiann Yang, NIST

Objectives: To provide fluid property and possibly droplet impact data for the study of the dynamics of droplet/surface interaction and its effect on burning cessation to be conducted by other PI s in the 2b projects.

Status: New project

(4) **Electrically Charged Water Mists for Extinguishing Fires—PI:** Charles H. Berman, AeroChem Research Laboratory, Titan Corp.

Objectives: To determine whether charged water droplets are drawn to a fire and are more effective at suppressing it.

Status: The project has been completed. For exposed, 5 and 10 cm diameter, turbulent heptane pool fires sitting well above the floor in a ventilated chamber, in the presence of a grounding electrode, extinguishment times were significantly reduced by charging the water spray at 5 and 15 kV. The charging also induced significant spreading of the water spray.

(5) **Development of a Self Atomizing Form of Water—PI:** Richard K. Lyon, EER, Inc.

Objectives: **To** make mist systems consisting of molecular hydrates and determine whether they "explode" downstream, increasing the effectiveness of total flooding; and to assess whether flashing of water can be affected by molecular hydrates and the approximate temperature range over which this is possible.

Status: The project has been completed. CO_2 hydrate was been found to disperse water effectively. However, the self-atomization was ineffective at extinguishing an obstructed flame. Upon analysis of the possible causes for the failures, the potential for success was deemed low and further research along this line was not recommended.

NEW AEROSOLS AND POWDER SUPPRESSANTS

(1) Powder-matrix Systems—PI: Donald Burgess, NIST

Objectives: To assess, and if reasonable develop, the capability for encapsulating in inorganic media, toxic but efficient fire suppression agents, enabling safe delivery to the fire, where the high temperatures will release the agent efficiently.

Status: New project

(2) Dendritic Polymers as Fire Suppressants—PI Nora Beck Tan, ARL

Objectives: To evaluate the potential for using metals, internally complexed in a dendritic polymer shell, as Halon 1301 replacements.

Status: New project

BETTER SUPPRESSANT DELIVERY

(1) Stabilization of Flames—PI Vincent Belovich, **AFRL**

Objectives: To understand how and the extent to which flame stabilization behind bluff bodies can reduce the observed effectiveness of a suppressant and guide identification of technologies that mitigate this limit to suppression efficiency; and to establish worst cases for extinguishment by gaseous, liquid, and solid suppressants and the increases in agent concentrations needed to cause flame extinguishment.

Status: A workshop was held to define practical geometries for consideration. Determination of the most effective flame stabilization geometries is now being accomplished by (1) Experiments: Preliminary results indicated that more stable flames were produced when the fuel was injected into the wake of a flow obstruction, producing a diffusion flame; and (2) Modeling of a variety of configurations: -Geometries with a cavity were generally more stable than the cases where a flame is stabilized downstream of a single bluff-body. Since both sets of results showed that the geometry of a cavity formed between two steps is the most stable, this is a likely candidate for the more-detailed testing later in the program.

(2) Dual Agent Approach to Crew Compartment Explosion Suppression—PI Douglas **S.** Dierdorf, **ARA** Corp.

Objectives: To determine the feasibility of a two-shot (powder, followed by water mist) system for fire suppression in a combat vehicle crew compartment.

Status: New project

(3) Suppressant Flow Through Piping—PI: John Chen, Lehigh University

Objectives: Develop and validate a computer code capable of predicting single- and two-phase hydrodynamic behavior of fire suppressant fluids during transport through piping systems: pressure losses and flow rates for a variety of fluids; through piping systems with various combinations of fittings, over a range of pressure and composition conditions, and for transient start and stop of flows, as well as for time-varying pressure heads.

Status: New project

NEW WAYS OF GENERATING SUPPRESSANTS
No Projects Underway

IMPROVED FIRE INERTION
No projects underway

FY1999 AND BEYOND

Solicitations for proposals for Element 4D (New and More Effective Fire Suppression Technologies that are Presently Conceptual) and Element 5E (Enhanced Powder Panels) were advertised in January 1998 and closed on 20 March 1998. Decisions on the received proposals are in progress.

The next solicitation for proposals will be advertised in December 1998, with a likely closure similar to this year. The announcements will appear in ***Commerce Business Daily***, on the SERDP website (http://www.serdp.gov/ngp-federal/ngp.htm), and on the soon-to-be-open NGP website (www.dtic.mil/ngp/).