When it Really Matters
ARFF vehicles have evolved to provide safe, rapid response to get agent transported from the fire station to the fire. I am going to talk to you today about getting that agent off of the truck and onto the fire in the most efficient ways.

In order to talk about the advancements in agent application technology, we need to look at the past.
Extensive testing was conducted in 1962 at the FAA facility that went by the name of National Aviation Facility and Experimental Center (NAFEC) and by the Naval Research Lab at China Lake. These test established the turret performance standards for NFPA, FAA and ICAO.
At the time the tests were conducted, protein foam and manually operated air aspirated turrets were the technology of the day.
These basic roof turret designs have evolved to include power operation and joystick controls. The large air aspirated nozzles have given way to smaller non air aspirated nozzle, more suited for AFFF foam.

However, the basic performance standards have not changed.
In the mean time, aircraft size and fuel loads have increased.
The B777 hold 8 times more fuel than the B737, and the A380 hold 13 times more fuel than the B737.

The 737 holds 6,295 gallons/23,828 liters of fuel.
The 777 holds 47,890 gallons/181,270 liters of fuel.
The A-380 holds 78,830 gallons/298,600 liters of fuel.

How much more fire extinguishing agent will you need?

Technology can make up some of the difference.
The Practical Critical Area (PCA) formulas established in the past were based on the length and width of the aircraft. It was assumed that as aircraft increased in fuselage size, the proportions of the length and width would increase accordingly.

We now know that aircraft, like the new Air Bus 380, carry twice as many passengers and 10 times as much fuel as the Boeing 737, but it has only a slightly larger footprint.

There are efforts underway to re-look at the PCA formulas. This is critical for aviation fire fighting because the PAC determines the amount of agent required for the airport index.
APPLICATION DENSITY

- Application density is gallons per minute (GPM) applied per square foot (SF) of fuel surface.
- AFFF/FFFP foam requires an application density of 0.07 GPM/SF.
- The standards committee doubled this to 0.13 GPM/SF to account for inefficiencies.

The application density is a very reliable number. For AFFF the rate of 0.07 GPM/SF is the maximum effective rate to extinguish any size of pool fire in 60 seconds. The gallon per minute flow rate then becomes a factor of the square foot size of the pool area (PCA).

An application rate of more than 0.07 GPM/SF will not extinguish the fire faster.

These are two important numbers that we will refer to later.
Three to five times as much agent as expected has been required to extinguish aircraft fires. And, this is with an application rate of double the maximum application density.
Vehicle Performance is only the Beginning

Shouldn’t we place more emphasis on Agent Management?

It’s not how fast you get there. It’s what you do with your agent once you are there.
One of the reasons the quantities are so far off is the misapplication of agent.

Political Foam – It looks good on CNN.
Aircraft today are stronger and safer. They are less likely to break up upon impact.

If the fire propagates to the interior, you have a large confined space interior fire.

Using conventional turrets, you had to wait until the fire broke through the skin to get large volumes of agent onto the fire.
Another reason for ineffectiveness of the conventional roof turret is the application techniques developed in the 1960’s testing. Raindrop is a term used to describe raining foam down on the fire from a distance. This technique was dictated by the protein foams of the time. Protein foam has very little burn back resistance. If the foam cover is broken, the exposed fuel can quickly reignite. The raindrop technique was developed to build up a thick foam blanket on the fuel without disturbing the surface.

AFFF foams solved the burn back problem, but if applied by the raindrop technique, much of the agent goes up in the heat plume.
Point of attack application from roof turrets accelerates agent but leads to over spray on windshield, which causes waste of agent. Because of obscured vision, fire fighters could not see what effect the agent was having on the fire.

Poor visibility caused the target to be directly obscured by the agent plume and by agent blow-back that was deposited on the vehicle windshield. Fire fighters could neither see how effective they were, nor where the agent was going.

A more direct agent discharge solves the heat plume problem, but can disturb the fuel surface creating an even larger fire.
WHAT IS A HIGH REACH EXTENDABLE TURRET?

- An articulating and/or telescoping aerial device mounted on the ARFF Vehicle.
- It provides extended vertical & horizontal positioning of the turret.

This tool took the turret off of the roof and provided a range of motion to position the turret from ground level to over 50 foot elevation.
The FAA Technical Center and the United States Air Force Research Lab took on the task of learning the potential of this new technology.

The Extendable Turret had the capability of positioning the nozzle high or low.

At first it was thought that the higher the reach, the more effective it would be in fighting fires. However, there was no significant improvement in extinguishment times.

As the nozzle was lowered, extinguishment times improved rapidly.
Parallel to ground application accelerates agent across the fuel surface. This type of low ground attack allows a 10 degree power cone spray effect that disperses agent more rapidly.

Test summary and conclusions: Optimum LFA crash vehicle approach mode conditions are frontal and tail approach, 0.13 GPM/ SF AFFF application rate, 0°, seat of the fire, agent delivery angle, delivered as low as possible.

The low application approach proved to be the most effective.

How many of you have been trained on using portable fire extinguishers? Were you taught to direct the stream at the base of the fire in a sweeping motion? The same technique proved to be true for large fires as well.
Slides would be in the red zone! This happens to be the area that you are tasked to protect.

Utilizing high reach extendable turret technology allows you to protect the entire aircraft by positioning on the nose and/or tail (depending on the size of the aircraft).

Conventional roof turret approach could require up to four vehicles (two each side) for the same coverage.
The top view is a conventional roof turret flowing at 500 gpm. This equates to and application density of .13 GPM/SF per the standards, but twice the theoretical rate.

The lower view is the Extendable Turret flowing 250 gpm, equal to the application density of .07 GPM/SF.

The net result is that the low positioned nozzle extinguishes the fire in half the time using half the agent.

This test was repeated dozens of times with the same results.
As a result of the previous tests, it only made sense to move the roof turret to a lower position on the vehicle to get the nozzle closer to the ground.
Remember the early slide showing manual operated turrets and protein foam? Look where the operator is positioned. Note the view he has of the fire.

Because of safety and manpower issues, turret controls were moved inside the cab. Foam agent was changed to AFFF. Now this is the view the operator has of the fire. How effective is he going to be in getting the agent on the seat of the fire.
Look at the improved visibility the operator has when looking over the water/foam flow instead of under it or placing the stream from an extendable boom far forward increasing the fields of view.
Comparative Evaluation of the Effectiveness of a High-Performance, Multi-position, Bumper-Mounted Turret to the Performance of a P-19 Roof-Mounted Turret

www.airtech.tc.faa.gov

- Safety
- Downloads
This is a comparison of roof turret performance vs. a low position turret. You will note that extinguishment times for the low mount turret are about half that of the roof turret.

Another interesting item is that there is not a significant change in effectiveness whether flowing at a .13 GPM/SF or .07 GPM/SF. Remember, applying AFFF at rates above .07 GPM/SF does not extinguish the fire faster. However, at the higher flow rate, we do use up the agent on the vehicle much faster.

<table>
<thead>
<tr>
<th>Approach Mode</th>
<th>Large Scale AFFF Delivery Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fire Surface -3, 850 SF</td>
</tr>
<tr>
<td></td>
<td>Average 90% Fire Extinguishment Time (Sec)</td>
</tr>
<tr>
<td></td>
<td>Delivery Method</td>
</tr>
<tr>
<td></td>
<td>Raindrop 45° Roof Turret</td>
</tr>
<tr>
<td></td>
<td>Raindrop 30° Roof Turret</td>
</tr>
<tr>
<td></td>
<td>Average</td>
</tr>
<tr>
<td>Low Flow@ 0.07 GPM/SF</td>
<td>56</td>
</tr>
<tr>
<td>High Flow@ 0.13 GPM/SF</td>
<td>50</td>
</tr>
<tr>
<td>Total</td>
<td>116</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Approach Mode</th>
<th>Large Scale AFFF Delivery Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fire Surface -3, 850 SF</td>
</tr>
<tr>
<td></td>
<td>Average 90% Fire Extinguishment Time (Sec)</td>
</tr>
<tr>
<td></td>
<td>Delivery Method</td>
</tr>
<tr>
<td></td>
<td>Raindrop 45° Roof Turret</td>
</tr>
<tr>
<td></td>
<td>Raindrop 30° Roof Turret</td>
</tr>
<tr>
<td></td>
<td>Average</td>
</tr>
<tr>
<td></td>
<td>Seat of The Fire 0° Bumper Turret</td>
</tr>
</tbody>
</table>
In the early 1990’s, a piercing nozzle was attached to the extendable turret. With hydraulic piercing power and a 50 foot articulating and telescoping arm, the piercing nozzle could quickly penetrate almost anywhere on the aircraft. Since it was not hand held, flows over 300 gpm were possible.
The FAA Technical Center took on the responsibility of testing this technology. Early theories were that the boom mounted piercing nozzle could be used to penetrate a fuselage and create a fire block to contain the interior fire to one end of the aircraft.

Hundreds of piercing tests were conducted to see what materials could be pierced and where was the best place to penetrate.
A full scale aircraft fire test was conducted at San Antonio in 1993. The aircraft was an older model 707 without flame retardant materials. The test scenario was to have an exterior fire under the tail propagate into the interior. Instruments inside the aircraft were monitoring temperatures. When the ceiling temperature reached 600 degrees, the piercing nozzle was to penetrate at a pre-determined point and block the fire from spreading to the rest of the plane.

However, the wind was blowing wrong and forced some of the flames against the plane’s skin. At the four minute mark the skin burned through dropping the galley and giving oxygen to the interior fire. Almost immediately a flash over occurred and the complete interior caught on fire. Ceiling temperatures went to 1200 degrees.

The piercing nozzle was brought into position and started pumping 375 gpm into the interior for 1 minute, 45 seconds. The entire aircraft interior was extinguished.
A view of what the piercing nozzle looks like inside the aircraft.

This is the same aircraft shown in the previous video. Note how the fire damage was mostly in the ceiling area where the flash over occurred. Survivable conditions were maintained at the seat back level and below.
HOW WELL DO THESE TECHNOLOGIES WORK?

- Less than 6000 gallons/22,710 liters of agent used

In December of 2003 a fully loaded cargo plane lost its right side landing gear and slid off the runway. About 4,000 gallons of fuel was on board. The fire or the crash caused the transfer valve to fail allowing all the fuel from the left side wing to also feed the fire. The nose of the aircraft was in a steep ravine not readily accessible by ARFF vehicles.

Less than 5,000 gallons of agent was used to extinguish the fire.
The fire fighting technique involves laying down a foam blanket to control the pool fire and cool the structure. Then focusing on the running fuel fires with bursts of dry chemical, keeping the foam flow constant.

Short burst of dry chemical when directed on target are very effective. It is important to minimize the amount of dry chemical used as it can cause a breakdown of the foam blanket.

At the end of the video, you will see what dry chemical looks like when it is not encapsulated. The operator shut off the water/foam flow before turning off the dry chemical.
One of the newest (and oldest) technologies is water mist. Foam attacks the fire triangle by removing oxygen. Water mist attacks the fire triangle by removing the heat. Breaking water droplets into a fine mist exposes a much larger water surface area to the heat of the fire. The fine mist will cool 100 times faster than conventional size water droplets and almost all of the water goes to extinguishment. There is very little run-off and the agent flow rates are very small compared to conventional nozzles. Also, this is an environmentally very clean agent.

High pressure, low volume nozzles have been around since the 1940’s. However, they were not able to break the water droplets fine enough to create mist that was comparable in fire fighting to that of large volume fog nozzles.

Two types of misting nozzles are under development. One technology utilizes ultra high pressure to create the mist and the energy necessary to transport the mist over distance. Ultra high pressure is in the range of 1,000 to 2,000 psi. Water is forced through a small tapered orifice under high pressure. This forces the water to accelerate to a very high velocity. As it exits the nozzle into the low atmospheric pressure, it vaporizes into a fine mist – still traveling at high velocity.

The Second Type uses high pressure air to vaporize the water into small droplets and this low pressure vaporized water is carried to the fire source. Much less nozzle back pressure is felt at the hand line or turret attachment.
ARFF vehicle compressed air foam systems are typically set between 15 and 20 to 1 expansion ratios. Thus, a compressed air foam system will produce four times as much foam from a given amount of water as a conventional foam system.

NOTE FOR BOB – Can of Beer and Shaving Cream.
Compressed air foam experiences an energy boost from the air injection. Low gpm flows of compressed air foam will travel as far as high gpm flows of conventional foam.

To produce 1,000 gpm of finished foam, conventional foam nozzles must flow about 250 gpm of liquid (expanded 4 to 1). To produce 1,000 gpm of compressed air foam we must flow 50 gpm of liquid (expanded 20 to 1).

This video is a compressed air foam system installed on a P-19 ARFF vehicle. The standard foam system is maintained. The operator can choose between conventional foam or compressed air foam. The fire fighting scenario might be to use standard foam to knock the fire down and switch to compressed air foam to build the foam blanket and protect exposures. As you can see, compressed air foam will cling to vertical surfaces.
Remember the application densities we have discussed? .13 GPM/SF is established by the standards, .07 GPM/SF is the maximum effective rate for AFFF foam. The Air Force conducted fire tests using compressed air foam. They concluded that an application density of .024 GPM/SF of compressed air foam was as effective as the .07 GPM/SF application rate of conventional foam. This means that compressed air foam is about 2 or 3 times more effective than conventional application.
We have essentially taken a vehicle that flows 1000 gpm/3,785 lpm at a .13 density application, moved to 500 gpm/1,893 lpm using the low angle approach at .07 density application and now can reduce to 166 gpm/628 lpm using compressed air foam – all with the same fire fighting capability. If you add injected Halotron or encapsulated dry chemical, the flow rate could be further reduced.

With these new technologies, your 1500 gallon/3,678 litter truck could have the fire fighting capability of a 9,000 gallon/34,065 litter truck using old roof turret performance standards. This is a theoretical figure. But an improvement of a factor of 3 is easily achievable.
Air aspirating nozzles are not dead. We don't know what the future of foam products will be. Air aspirated nozzle may be necessary. A new compact version of the air aspirated nozzle uses new technology to increase the aeration without the need for the long barrels. This 1,000 gpm nozzle is about 20” long.
New tools are available to advise the operator the status of the agent on board. We have shown that attacking with a high flow rate may not be any more effective than a low flow rate. A high flow rate on the primary turret will empty the vehicle in two minutes. This display advises the operator how many minutes and seconds of agent are left at the current flow rate. It allows him to make a decision as to how to use the remaining agent or to switch to a lower flow rate to be more effective. Once the agent is gone, the fire will gain control during the refill process. It is much better to use the agent on board to its maximum effectiveness.
The Agent Management System provides critical information to the operator regarding agent discharge time remaining, turret flow status and water tank level.

The system is located in direct view of the operator so he can keep focused on the fire fighting effort while getting the information he needs.
LARGER AIRCRAFT REQUIRES MORE STAND-OFF DISTANCE

ARFF vehicles will not be able to get as close to the aircraft as in the past.
Extendable turrets are increasing in size to accommodate the larger aircraft. The increased height is not as important as the increased reach. Longer stand-off distances are required for double deck evacuation slides and vehicle protection in event of landing gear collapse.

This particular design features two nozzles. A high volume nozzle at the 50 ft. level on the upper boom and a low volume nozzle at the tip. The low volume nozzle is used for engine, wheel/brake and interior fires. The high volume nozzle is used for large spill fire control.
Do a risk assessment.

Recognize there is a problem.

Seek new & improved technology to better improve fire fighting capabilities and minimize risk.

Train in the effective use of this technology.
HOW DO I GET THE NEW TECHNOLOGY?

- You have to take the initiative.
- Specify the technology that best accomplishes your goals.
- Add requirements to your new truck specifications and purchases.
- Investigate what can be upgraded on existing vehicles.
This Technology Is Spreading Around the World
Driven by a Vision
Focused on Results