ARCTIC RESPONSE TECHNOLOGY
OIL SPILL PREPAREDNESS

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Waypoint Aeronautical Corporation
SL Ross Environmental Research Ltd.

CONCEPTUAL DESIGN FOR A LONG-RANGE AERIAL IGNITION SYSTEM FOR IN SITU BURNING - FINAL PROJECT REPORT

ARCTIC OIL SPILL RESPONSE TECHNOLOGY – JOINT INDUSTRY PROGRAMME

The oil and gas industry has made significant advances in the ability to detect, contain, and cleanup oil spills in arctic environments (Potter et al., 2012). Ongoing research continues to build upon more than fifty years of examining all aspects of oil spill preparedness, oil spill behaviour, and available options for oil spill response in the Arctic marine environment. This research has included hundreds of studies, laboratory and basin experiments, and field trials, conducted in the United States, Canada, and Scandinavia. To build on existing research and improve technologies and methodologies for arctic oil spill response, members from the IPIECA-Oil Spill Working Group, Industry Technical Advisory Committee (ITAC) and the American Petroleum Institute-Emergency Preparedness and Response Programme Group formed a joint committee in 2009. The committee's task was to review the oil and gas industry's prior and future work scope on prevention and response to oil spills in ice in order to identify and prioritise technology advances and research needs. One outcome was the recommendation to establish the Arctic Oil Spill Response Technology Joint Industry Programme (JIP) that would undertake targeted research projects identified to improve industry capabilities and coordination in the area of arctic oil spill response.

The JIP was launched in January 2012 and over the course of the programme is carrying out a series of advanced research projects in six key areas: dispersants, environmental effects, trajectory modelling, remote sensing, mechanical recovery, and in situ burning (ISB).

Recognizing the limitations of mechanical recovery systems available today, the JIP Mechanical Recovery research project was initiated with the following objectives:

- Examine results obtained from previous research projects and identify further improvement opportunities for design of mechanical recovery equipment and response strategies for oil spill recovery in ice;
- Develop a selection process by which novel concepts can be rigorously examined; and
- Select and develop the most promising concepts.

TABLE OF CONTENTS

FIGURES

TERMINOLOGY AND ACRONYMS

"Aircraft Certification Office"	(ACO)
"Aircraft Evaluation Group"	(AEG)
"Airplane Flight Manual Supplement"	(AFMS)
"Arctic Oil Spill Response Technology Joint Industry Program"	(JIP)
"Compliance Checklist"	(CCL)
"Computational Fluid Dynamics"	(CFD)
"Conformity Inspection Plan"	(CIP)
"Designated Engineering Representative"	(DER)
"Designated Airworthiness Representative"	(DAR)
"European Aviation Safety Agency"	(EASA)
"Federal Aviation Administration"	(FAA)
"Health Safety and Environment"	(HSE)
"In Situ Burning"	(ISB)
"Instructions for Continued Airworthiness"	(ICA)
"International Association of Oil and Gas Producers"	(IOGP)
"Manufacturer Inspection District Office"	(MIDO)
"National Automated Conformity Inspection Process"	(NACIP)
"Project Specific Certification Plan"	(PSCP)
"Special Federal Aviation Regulation"	(SFAR)
"Supplemental Type Certificate"	(STC)
"Type Certificate"	(TC)
"Type Certificate Data Sheet"	(TCDS)
"Type Inspection Authorization"	(TIA)
"Velocity Stall Speeds"	(Vso)
"1.3 Velocity Stall Speeds"	(1.3 Vso)

EXECUTIVE SUMMARY

In January 2012, members of the international oil and gas industry launched a collaborative effort to enhance Arctic oil spill capabilities under the auspices of the International Association of Oil and Gas Producers (IOGP). This collaboration, called the Arctic Oil Spill Response Technology Joint Industry Program (JIP), was created to expand industry knowledge of, and proficiencies in Arctic oil spill response.

Over the course of the program, the JIP is carrying out a series of advanced research projects in laboratory conditions on six key areas of research: dispersants, environmental effects, trajectory modelling, remote sensing, mechanical recovery and in situ burning (ISB).

The objective of the ISB research project is to develop improved ignition systems to facilitate the use of ISB in offshore arctic environments by extending offshore reach and shrinking response times.

Previous ground based experiments with modified Heli-Torch ignition systems proposed for fixed-wing aircraft showed that it is possible to ignite gelled fuel in winds up to 100 knots: the minimum airspeed required for use of fixed wing aircraft for ISB.

Following the success of preliminary ground testing, the JIP sought contractors to conduct research investigations to develop a long-range aerial ignition system to facilitate the use of ISB in offshore Arctic environments, including situations where safety concerns preclude the use of vessels as a nearby base for helicopter ignition operations. The JIP contracted Waypoint Aeronautical Corporation, Everett, Washington, with contribution from SL Ross Environmental Research, Ltd., Ottawa, Canada.

In this report, Waypoint presents a conceptual solution for a long-range aerial ignition system for in situ burning. The report identifies suitable aircraft (fixed wing and rotary), presents a conceptual design for a long-range aerial ignition system, presents the Federal Aviation Administration (FAA)/European Aviation Safety Agency (EASA) certification process and presents proof of concept flight test plans and locations. Following careful review of candidate aircraft, the fixed-wing Casa 212 and rotorcraft Sikorsky S-92 were chosen as the aircraft best-capable of meeting design and operational requirements. The design, manufacture and certification of the proposed long-range ISB system would take approximately 1 ½ to 2 years.

1. PROJECT SUMMARY AND CONCLUSIONS

The objective of the ISB research project was to provide JIP with a long-range solution for an aerial ignition system for ISB through the following objectives:

Task 1: Identify suitable aircraft.

Task 2: Develop conceptual design for a distribution and ignition system.

Task 3: Identify FAA/EASA approval requirements.

Task 4: Identify location for on-shore testing

Task 5: Identify priorities for integrated systems testing.

Waypoint delivered five key deliverables in furtherance of the tasks.

1.1 Task: 1: Identify suitable aircraft.

There are several aircraft commercially available that could meet the criteria needed to effectively carry out a long range ISB operation. Waypoint analyzed over 23 candidate aircraft for the project. Mission requirements eliminated the majority of the candidate aircraft based on operational delivery speeds and the necessity for a rear cargo door. The top two candidate aircraft were chosen for further consideration and conceptual kit design: the Casa 212 and Sikorsky S-92. Both aircraft could effectively carry out a long range ISB mission.

1.2 Task 2: Develop conceptual design for a distribution and ignition system.

The conceptual design for a long range distribution and ignition system contains four major sub-systems: Gel Fuel Storage and Pumping – Consisting of a storage tank, pump, plumbing and heat blankets; Ignition System –The design includes a simple spark ignition system, piezoelectric or electrode, aircraft grade; Hose and Drogue Chute Assembly – Necessary to allow dispensing of the ignited gel fuel at a suitable distance aft of the aircraft to ensure no fuel swirls around and returns to any airframe area; and Control System – Presents status and control of the dispensing system, and necessary auxiliary systems such as fire detection and extinguishing. System design and manufacture would take approximately 9 months. The system would maximize the use a number of "off the shelf" aeronautical and non-aeronautical parts to save on design and manufacturing costs.

1.3 Task 3: Identify FAA approval requirements.

Certification of the ISB system will require obtaining a Supplemental Type Certificate (STC) from the FAA under 14 Code of Federal Regulations (CFR) Part 21, with validation by EASA. The certification process from submittal of the initial STC application paperwork to the issuance of the STC will take approximately 1 ½ to 2 years. This project sets forth the STC application process in detail. Waypoint has substantial experience obtaining STCs, including for tankering of fuel and other flammable fluids. Waypoint does not anticipate any issues that would prohibit obtaining certification of the proposed ISB system in the proposed timeline.

1.4 Task 4: Identify location for on-shore testing.

Waypoint evaluated private and military airports across the United States for suitable on-shore test locations. The primary requirements for a test site location, for both ground and in-flight testing, include: remote location with exclusive availability; 10,000 ft concrete runway availability; fire department and support equipment; oil cleanup services; cold weather conditions; and burn permits available. Four test sites were identified that would meet the on-shore test requirements. Waypoint has given preference to the Moses Lake, Washington location based on meeting all of the flight test location requirements, as well as past experience with successful flight testing at this location.

1.5 Task 5: Identify priorities for integrated systems testing.

Waypoint has proposed ISB system testing in two phases: Phase 1 truck mounted testing and Phase 2 aircraft mounted testing. Goals of concept testing include: (1) proving the efficiency and effectiveness of the design; (2) proving the safety of the equipment; and (3) providing confidence to move forward with full product development and certification. Ground testing the system first as a truck mounted system will allow for the design to be proven, and modified as necessary, prior to full flight test. Proof of concept ground and flight testing will take approximately four months, with a base cost of approximately [$300,000].

2. PROBLEM STATEMENT

The burning of oil has for decades been an acknowledged option for the elimination of spilled oil on land, in wetland areas, and in an offshore environment. Most of the burns that received significant media/public attention were those that were accidental or deliberate controlled field trials (Allen, 1987). In the early 1980s, interest grew rapidly around the potential of controlled burning as offshore drilling progressed in the Beaufort Sea off Alaska. It was recognized that spilled oil spread less quickly and retained its lighter volatiles under extremely cold conditions, and that the presence of ice could actually enhance the burning of oil by damping wave action and providing a natural barrier to further limit the spread of oil. By keeping spilled oil well above its minimum ignition thickness of 1 mm for fresh crude, 2 to 3 mm for evaporated crude, burns could be carried out under extreme Arctic temperatures. Burn trials demonstrated that oil could be retained under and within ice for several months, keeping the oil fresh, un-emulsified and volatile for successful ignition when exposed by drilling into the ice or after its natural migration through brine channels in early spring.

As the interest in deliberate burning grew, there was a rapid improvement in fire boom and igniter technology. Burning was recognized as one of the most promising response techniques for the Arctic as well as for temperate and tropic conditions offshore and inland (Allen, et al., 1993; Buist, et al., 1994). Both hand-held igniters and aerial ignition systems were tested and modified for use during field trials and actual spill events. All of these efforts, involved the deployment of igniters by hand or from a helicopter.

During the 1989 Exxon Valdez spill in Prince William Sound, a Heli-Torch was flown and used on highly weathered oil contained within fire-resistant booms. The Heli-Torch could be used safely and effectively nearshore and typically within 10 to 20 miles of the Valdez Airport; however, because of delays in securing authorization, getting on location quickly and having to work with high levels of emulsification, none of the Heli-Torch operations were successful. A single and very successful ignition was conducted on the evening of the second day following the grounding of the Exxon Valdez. At least 15,000 gallons, and as much as 30,000 gallons of North Slope crude oil were eliminated from within a fire-resistant boom in less than an hour of burning (Allen, 1990). Ignition was carried out with a small hand-held baggie of gelled gasoline released from one of the boom-tending vessels. This single successful burn was the first deliberate ignition of oil contained within a fire-resistant boom during a major spill event offshore. It proved that a small packet of gelled fuel could serve as an ignition point for lightly weathered crude oil floating on near-freezing water.

Additional tests of aerial ignition with oil in fire boom continued over the next several years, aimed primarily with the use of a Heli-Torch (Fingas, 1995; Thornborough, 1997). These tests were successful, but depended upon nearby logistical support for landing and refueling of the helicopters. These trials also involved payloads under 50 gallons of gelled fuel per sortie. The need for enhanced ignition, especially during long-duration spill events far offshore, became evident during the Gulf of Mexico Deepwater Horizon MC-252 oil spill. The use of controlled burning during that event in 2010, over a 3-month period, typically 40 to 50 miles offshore, created unique challenges for the burn teams that ultimately conducted over 400 burns eliminating between 220,000 to 310,000 barrels of oil (Allen, et al., 2011). Because of the distances offshore and the lack of support facilities for helicopters and Heli-Torch operations, burn teams were restricted to the use of hand-held igniters and the labor-intensive efforts to assemble and deploy approximately 1,200 igniters.

During any major spill event, especially far offshore in remote locations (e.g., Arctic waters off Alaska and other polar regions), there is an acknowledged need for an aerial ignition system that can deliver large payloads of gelled fuel, hundreds of miles from its support airport, and be able to stay on location long enough to locate target oil slicks (or patches of oil on/among ice floes). Offshore exploration drilling and production operations at sites on the order of 100 miles or more from onshore support facilities will clearly depend upon one or more suitable fixed-wing aircraft for the ignition of spilled oil. This need will be even greater during any ongoing spill event, such as blowout, where oil could conceivably be released on, into and beneath extensive regions of moving ice. While highly unlikely with current advancements in drilling practices, well control, capping techniques and relief well capabilities, there is the remote possibility that a late-season blowout could result in the release of large volumes of oil over tens to hundreds of miles of moving ice before being brought under control. While such an unlikely event must be planned for, it should also be recognized that such a release would likely be relatively narrow in swath (on the order of 1,000 feet or less) as it is contained naturally within the wake of ice moving past the spill source platform or on/within ice downstream. Depending upon the nature, volume and timing of any major release of oil in the Arctic, there is a very strong need to be able to ignite spilled oil over a possibly long stretch of moving ice, far offshore, as it is exposed naturally in melt pools during spring, or as it is exposed with icebreakers shortly after release or later during the winter/breakup seasons.

Proof of concept field testing ("Phase 1 Testing") was conducted in 2010 and 2011 to determine whether gelled fuel could be ignited at air speeds of 80mph or higher, the minimum air speed anticipated for ignition from a fixed-wing aircraft (Preli, T. et al., 2011 (**Attachment 1 hereto**)). Phase 1 Testing proved that gelled fuel could be effectively ignited at wind speeds between 80mph and 100mph.

Following the success of Phase 1 Testing, the JIP sought contractors to conduct research investigations to develop a long-range aerial ignition system to facilitate the use of in situ burning in offshore Arctic environments, including situations when safety concerns preclude the use of vessels as a nearby base for helicopter ignition operations and Waypoint Aeronautical was selected.

In this report, Waypoint presents a conceptual solution for a long-range aerial ignition system for in situ burning. The report identifies suitable aircraft (fixed wing and rotary), presents a conceptual design for a long-range aerial ignition system, presents the Federal Aviation Administration (FAA)/European Aviation Safety Agency (EASA) certification process for the Specified Aircraft Criteria and proof of concept flight test plans and locations.

3. SPILL SCENARIO FOR LONG RANGE IGNITION

The basis for these calculations is a spill scenario involving a release of crude oil from a deep subsea blowout under moving pack ice in Arctic waters. The oil is sheared into droplets by the escaping gas at the wellhead (Figure 1). The high pressure and cold water temperatures at depths greater than about 400 m causes the gas to form solid hydrates, which separate from the rising plume (Figure 2): at the same time the natural gas is dissolving in the seawater. Before the plume reaches the surface, it consists of only oil droplets rising relatively slowly due to their buoyancy. When the oil droplets reach the surface, they impinge on the bottom of the ice sheet (Figure 3) drifting over the site.

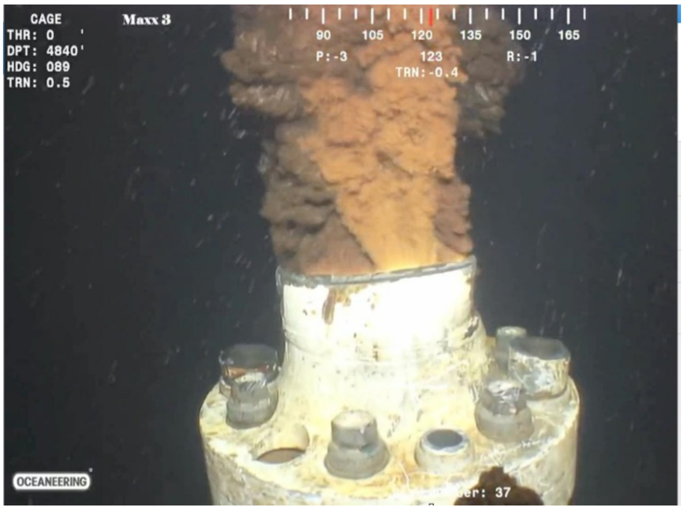


Figure 1. Oil and gas exiting the Macondo wellhead at 1,450 m depth in the Gulf of Mexico (Source: Oceaneering).

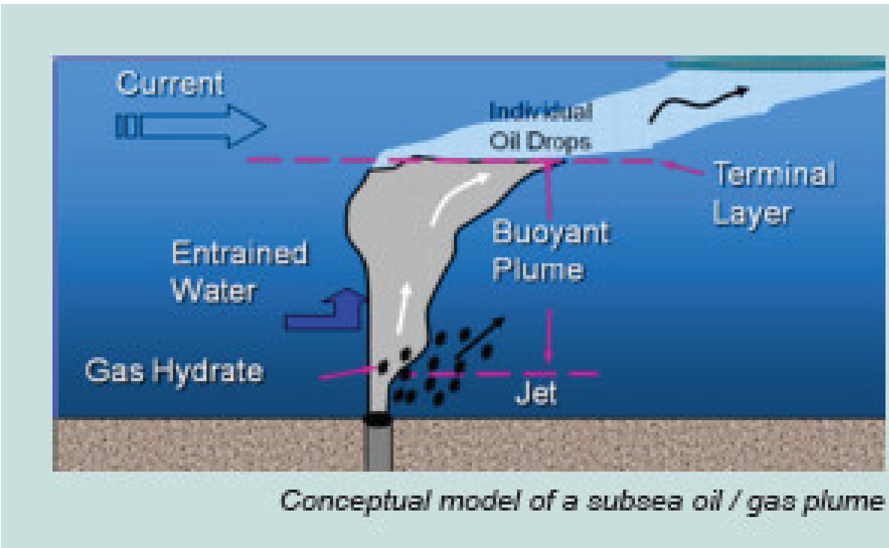


Figure 2. Conceptual model of the fate of gas and oil droplets as they rise to the surface (Source: API).

The thickness of the oil "painted" on the under-surface of the moving ice sheet is a function of the velocity of the ice and the hydrodynamics of the blowout. Figure 3 shows a graph of the cross-section of the computer-predicted oil layer thickness under the ice from a 50,000 barrel/day blowout in 500+ m of water with an average ice movement of 21 cm/s during fall freeze-up. Figure 4 shows the same for the winter season when the average ice movement is 5 cm/s. The thickest oil is in the center of the oiled strip: 90% of the oil is contained in a width of approximately 1 km wide.

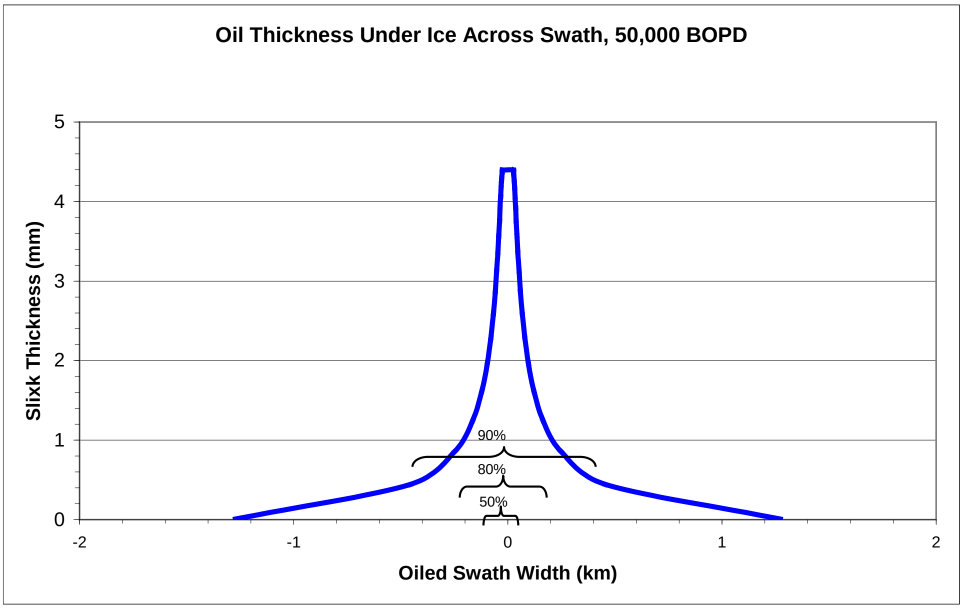


Figure 3. Predicted thickness profile of oil under ice moving over the 50,000 BOPD blowout at 21 cm/s during fall freeze up (distance across swath containing 50%, 80% and 90% of oil shown) (Source: SL Ross Environmental Research).

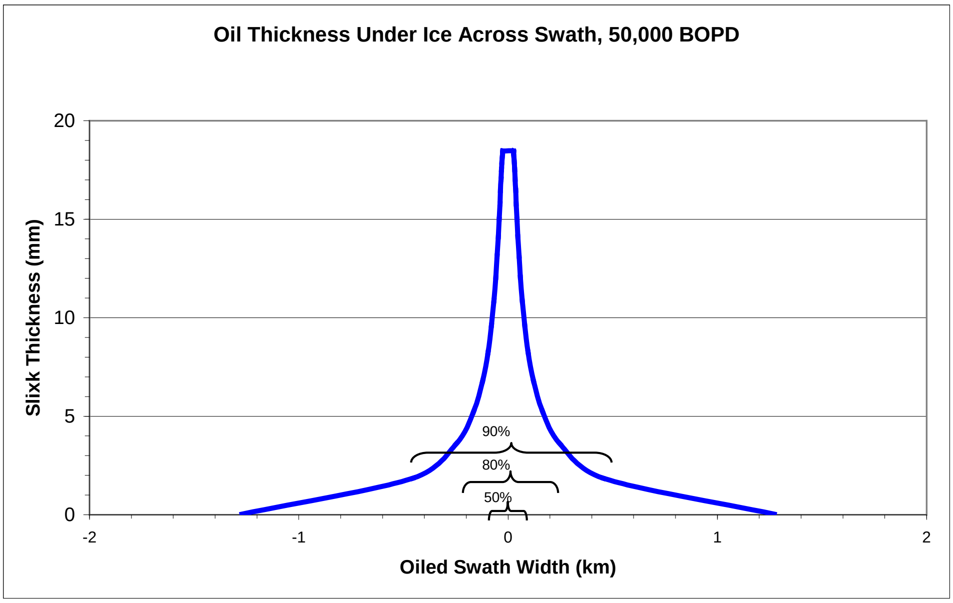


Figure 4. Predicted thickness profile of oil under ice moving over the 50,000 BOPD blowout during winter at 5 cm/s (distance across swath containing 50%, 80% and 90% of oil shown) (Source: SL Ross Environmental Research).

The oil droplets under the ice sheet will be trapped by the natural roughness of the under ice surface (Figure 5). If it is still winter, the ice sheet will grow downward and encapsulate the oil droplets in a day or two (Figure 6): a small fraction may rise into open leads in the ice sheet. The oil trapped under the ice forms a layer in the ice sheet, like a sandwich (Figures 7 and 8), where it remains trapped and does not weather until the ice sheet starts to warm in spring. The oil drifts with the ice until spring breakup.

Figure 5. Oil droplets "painted" on underside of ice (Source: Dome Petroleum).

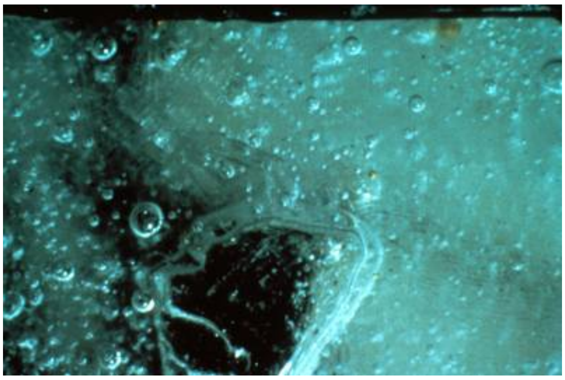


Figure 6. Oil droplets encapsulated by ice growing downward (Source: Dome Petroleum).

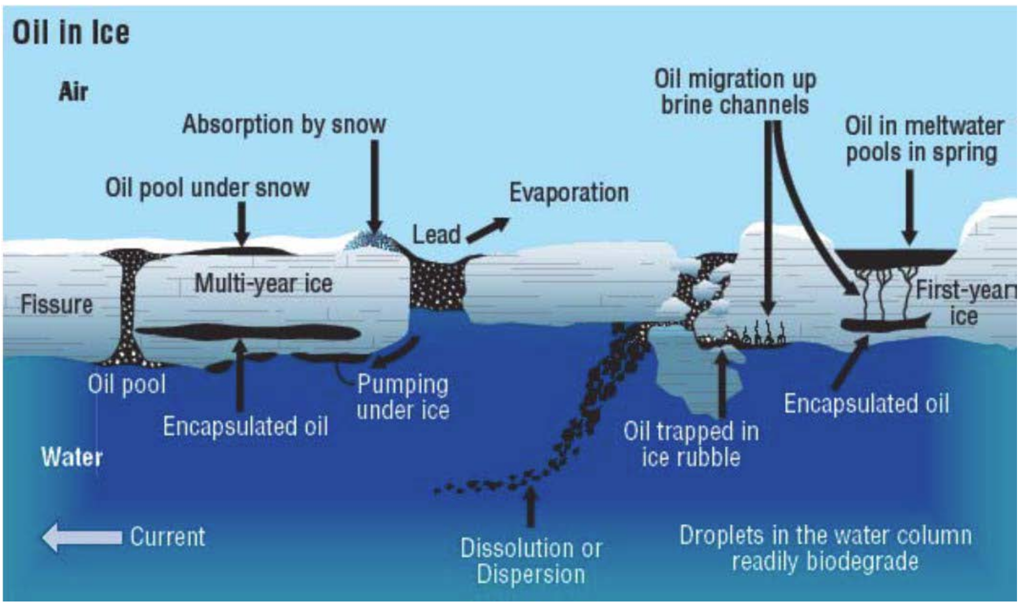


Figure 7. General fate of oil spilled under or on ice (Source: ExxonMobil).

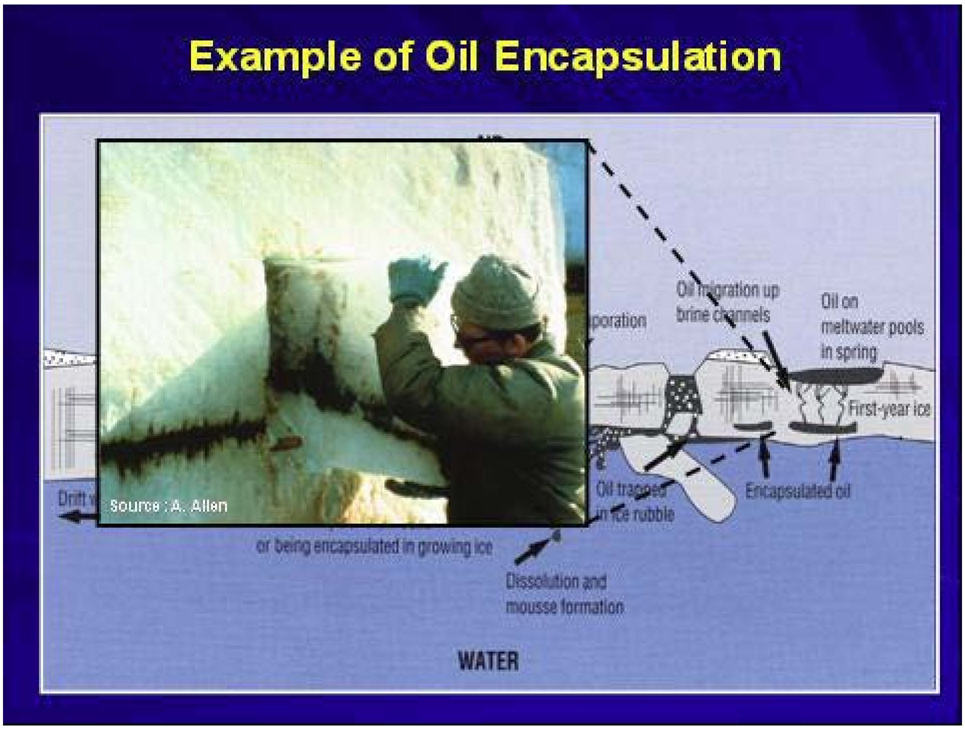


Figure 8. Oil encapsulated in a growing ice sheet that was cut and lifted up for examination (Source: A. Allen).

Once the ice sheet warms in spring, channels begin to open up vertically in the ice sheet as the frozen brine pockets melt and drain out. This allows the layer of trapped oil to migrate up to the surface as the brine channels fill with seawater. Figure 9 shows a core taken through a layer of encapsulated oil in spring and illustrates the upward movement of the oil through brine channels.

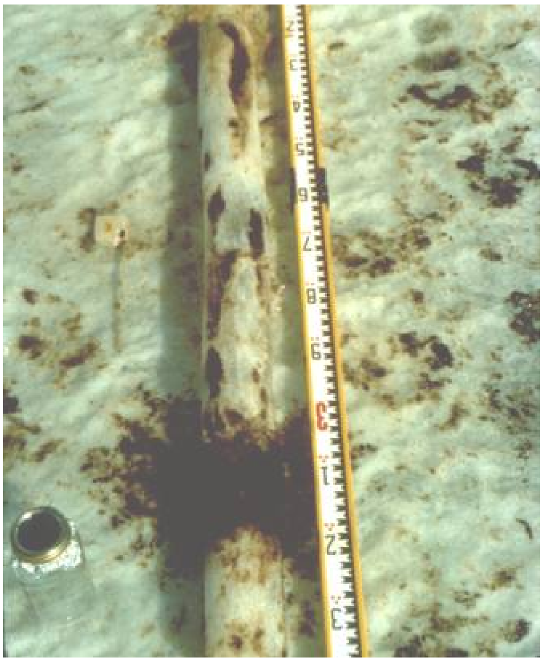


Figure 9. Oil layer “sandwiched” in ice until brine drainage channels open in spring – no weathering (Source: Dome Petroleum).

The oil surfaces in melt pools of water on the ice sheet surface and begins to evaporate. The individual droplets surface (Figure 10), and are swept to the downwind edge of the melt pool where they accumulate into thick (≈ 10 mm) slicks (Figure 11).

Figure 10. Thick oil layers rise to surface through brine channels to collect in melt pools (Source: Dome Petroleum).

Figure 11. Oil blown to downwind edge of melt pools as 1-cm thick slicks (Source: Dome Petroleum).

The timing of the appearance of the oil in melt pools depends on the weather (i.e., spring conditions), the thickness of the oil under the ice and the time of year it was spilled (i.e., fall, winter or spring). Thin oil layers (≈ 1 mm) will appear more slowly (Figure 12) than thicker pools (≈ 1 cm) under the ice (Figure 13). Figure 14 illustrates the rate of appearance of oil on the ice surface from a thick layer of oil frozen in the ice sheet. Figure 15 shows the distribution of oil slick sizes on melt pools in spring from an experimental subsea blowout under ice: 85% of the volume of oil in the melt pools is contained in slicks 5 m^2 and greater of which there are about 30 per ha (3,000 per km^2). If a subsea blowout were to occur in late fall and continue under the ice until the next spring, the strip of oiled ice could be 100s of kms long.

In any case, there will a window of opportunity of several weeks during spring melt to aerially ignite and burn the oil. Figures 15 through 18 illustrate such burns. In general, the average oil removal efficiency for an individual melt pool burn is on the order of 80%. The overall oil removal efficiency for springtime ISB operations is a function of oil distribution and igniter targeting efficiency.

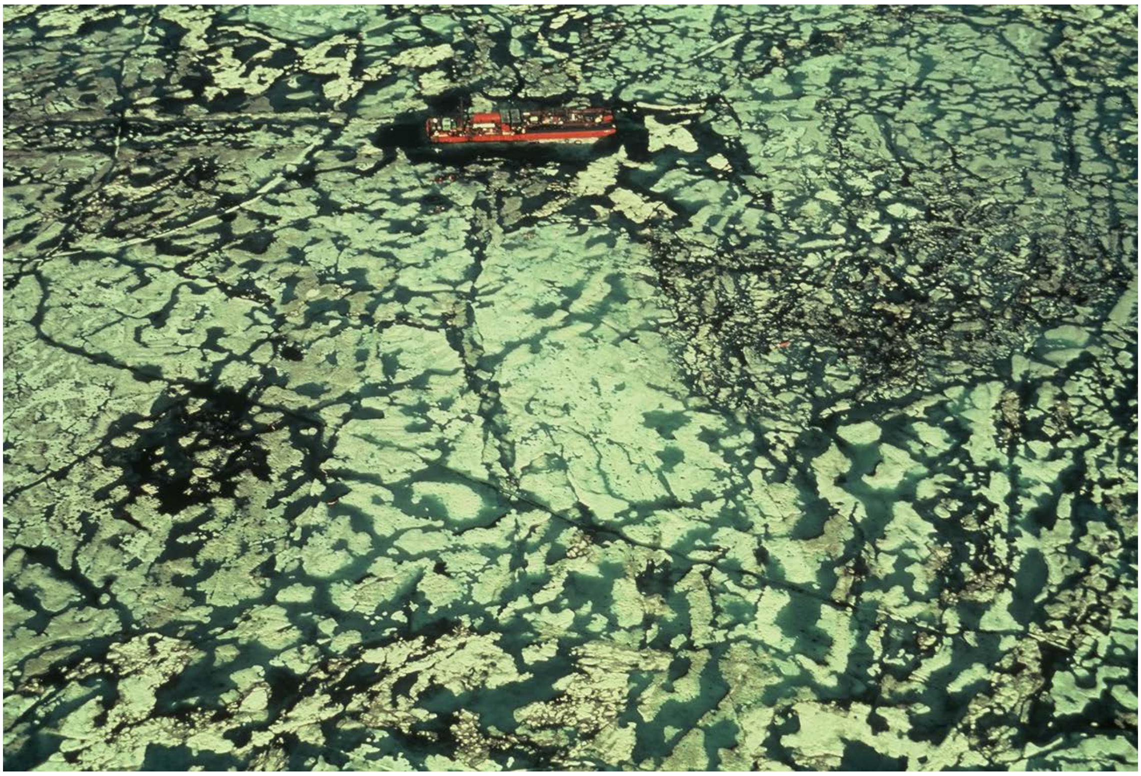


Figure 12. Oiled melt pools from subsea blowout under ice with 1-mm coverage surfacing in late spring (Source: D. Dickins).

Figure 13. Balaena Bay thick oil release surfacing in early spring (Source: D. Dickins).

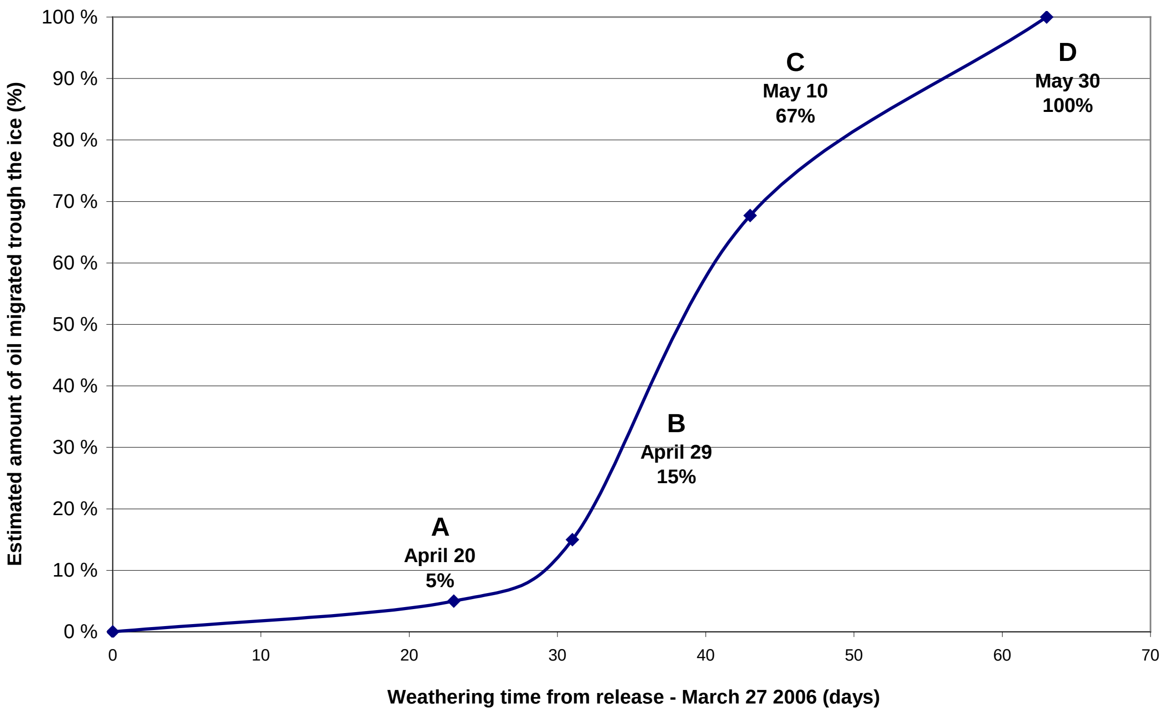


Figure 14. Exposure of encapsulated oil (Source: D. Dickins).

Table 1.Oiled melt pool slick size ranges.

	Oil Pool Size Range (pools greater than)					
	All	1 m^2	5 m^2	10 m^2	20 m^2	100 m^2
No of pools/ha	80	60	30	15	4	2
% oil in range	100	95	85	75	45	40

Figure 15. Burning oil on melt pools with igniters dropped from a helicopter during a simulated blowout under ice in McKinley Bay NWT (Source: Dome Petroleum).

Figure 16. Ignition and burning of oil on melt pools is effective removal technique, with efficiency depending on oil distribution and igniter targeting (Source: Dome Petroleum).

Figure 17. ISB at Balaena Bay experimental spill under ice (Source D. Dickins).

Figure 18. Aerial view of Balaena Bay in situ burn (Source: D. Dickins).

4. AIRCRAFT SELECTION FOR LONG RANGE IGNITION

Based on results from Phase 1 Testing and historical ISB operations, the JIP specified the following general criteria for aircraft capable of effectively carrying out a long-range in situ burning operation:

Aircraft Criteria for in Situ Burning:

Specifications found in the RFP:

1)	Gelled Fuel delivery speeds	Not to exceed 100 knots (based on Phase 1 Testing)
2)	Delivery Characteristics	Safe flight and good visibility at 50-100 feet AGL
3)	Loitering/ Holding Speeds	Safely at low altitude and under 100 knots airspeed
4)	Tank Size	500-1000 US gal (estimated 5-10k pound payloads)
5)	Range	Several hundred miles off shore
6)	Transit Speed	Greatest possible, while meeting loitering speed criteria
7)	Airframe Type	Rotorcraft or fixed wing, min. two turbine engines
8)	Airframe	Worldwide availability, adequately modified for mission
9)	Special Features	Short field, all weather, gravel runways, ease to modify, pressurized vs non-pressurized, rear loading

4.1 Aircraft Survey

Based on the stated requirements, 23 candidate aircraft were compiled that: (1) meet all or most of the stated criteria; (2) are commercially available; (3) are type certified for worldwide acceptance; and (4) have maintenance and spares support. The candidate aircraft included large aircraft, small aircraft, and helicopters.

Each candidate aircraft was analyzed for all of the operational criteria in actual flight plan models:

- Velocity Stall Speeds (Vso)
- 1.3 Velocity Stall Speeds (1.3 Vso)-Minimum acceptable safe delivery speed without stall
- Delivery Speeds
- Delivery Characteristics
- Loitering Speeds
- Payload Capabilities
- Transit Speeds
- Range
- Global Acceptance

Candidate aircraft were reviewed for compatibility with the preliminary in situ system design. Considerations included:

- Approved cargo system
- Palletized system
- Floor loading weight considerations
- Size of tanks
- Weight and balance considerations
- Pallet size
- Commercial pallets
- Military pallets
- Built for 9G crash loads for flammable liquids
- Rear cargo door (Available for aft facing airborne delivery)
- Side cargo doors (Available for side booms or aft facing delivery system)

- Weight and balance-control system adaptable to different configurations
- Pumping power requirements
- Electrical by aircraft generators
- Pneumatic or hydraulic
- Compressed air
- Auxiliary diesel power

Range versus payload calculations were completed for the top 15 candidate aircraft. The full set of range versus payload calculations are included as **Attachment 2** hereto. The full candidate survey follows.

Compilation of Candidate Aircraft

Large Aircraft	Vso*	1.3Vso*	Optimum Delivery Speed	Payload 500 NM offshore	JIP Mission Range	Gross Weight	Worldwide Availability	Cargo System Aft Ramp	Transit Speed	All Weather	Gravel Runway	FAA Certification	EASA Certification	Notes: Major Considerations
CASA 235	86 Knots	112 Knots		7,384 lbs		34,830 lbs	YES	YES	245 knots	YES	YES	YES	YES	6
ATR 42-320	84 Knots	109 Knots		5,657 lbs		36,825 lbs	YES	NO	260 Knots	YES	YES	YES	YES	1,6
ATR 42-500	86 Knots	112 Knots		7,567 lbs		41,005 lbs	YES	NO	300 Knots	YES	YES	YES	YES	1,6
Lockheed LM-100J/C130	89 Knots	116 Knots		30,000 lbs		164,000 lbs	YES	YES	355 knots	YES	YES	YES	NO	3,6
Dash 8	86 Knots	112 Knots		17,741 lbs		65,200 lbs	YES	NO	322 knots	YES	YES	YES	YES	1,6
BAE 146	92 Knots	120 Knots		Unable		93,000 lbs	YES	NO	414 knots	YES	YES	YES	YES	1,6
Convair 580F	88 knots	114 Knots		Unable		58,156 lbs	YES	NO	269 knots	YES	YES	YES	NO	1, 3,6

Small Aircraft	Vso	1.3Vso	Optimum Delivery Speed	Payload offshore	JIP Mission Range	Gross Weight	Worldwide Availability	Cargo System Aft Ramp	Transit Speed	All Weather	Gravel Runway	FAA Certification	EASA Certification	Notes: Major Considerations
CASA 212	62 Knots	81 Knots	110-120 Knots			17,860 lbs	YES	YES	170 knots	YES	YES	YES	NO	3, See Payload Range Charts
Shorts 330/360 Sherpa	74 Knots	96 Knots				25,600 lbs	YES	YES	220 knots	YES	YES	YES	NO	3, 5
Dash 7	75 Knots	98 Knots				41,000 lbs	NO	NO	210 knots	YES	YES	YES	NO	1, 3, 4
DHC-4A Turbine Conversion	67 Knots	87 Knots	105-110 Knots			28,500 lbs	YES	YES	150 knots	YES	YES	YES	NO	3, See Payload Range Charts
Dornier 228	75 Knots	98 Knots				14,110 lbs	YES	NO	190 knots	YES	YES	YES	YES	1, 8
Grumman S2T						27,500 lbs	YES	NO	220 knots	YES	YES	NO	NO	1, 3, 4
Shorts Skyvan	60 Knots	78 Knots				12,300 lbs	YES	YES	170 knots	YES	YES	YES	NO	3, 8, 9
Basler BT-67	58 Knots	76 Knots				30,000 lbs	YES	NO	200 knots	YES	YES	YES	NO	1, 3

Helicopters	Payload	Payload	JIP Mission Range	Worldwide Availability	Cargo System Aft Ramp	Transit Speed	All Weather	FAA Certification	EASA Certification	Notes	Comments
Columbia 234 Chinook LR	10,932 lbs			YES	YES	130 Knots	YES	YES	NO	3	
Eurocopter AS332 Super Puma	5,943 lbs			YES	YES	139 Knots	YES	YES	YES	1,2	See Payload Range Charts
Sikorsky S92	4,875 lbs			YES	YES	137 knots	YES	YES	YES		See Payload Range Charts
AW 139	3823 lbs			YES	NO	150 Knots	YES	YES	YES	1, 8	
AW 189	5,469 lbs			YES	NO	150 Knots	YES	YES	YES	1	
Bell 214ST					NO		YES	YES	NO	1	Limited production/ certification
Bell 412				YES	NO		YES	YES	YES	1, 8	
Sikorsky S70				NO	NO		YES	YES	NO	1, 3, 4, 10	

Note Codes:

1. No Aft Ramp for aerial delivery
2. No Palletized Cargo System
3. No EASA Certification
4. No FAA Certification
5. Limited availability
6. High delivery speed
7. Poor slow speed handling
8. Limited Payload
9. Limited Range
10. Restricted Category Cert.

*Vso-Velocity Stall Speed

*1.3 Vso-1.3x Velocity Stall Speed

Waypoint Recommendations

4.2 Aircraft Selection

Based on the full candidate aircraft survey, the fixed-wing Casa 212 and rotorcraft Sikorsky S-92 were chosen as the candidate aircraft best-capable of meeting operational and preliminary design requirements.

The criteria for safe delivery speed under 100 knots eliminated all large fixed-wing aircraft from consideration. Following preliminary design review, it was determined that a rear loading ramp was an essential feature to meet mission and design requirements. The necessity for a rear loading ramp eliminated all rotorcraft apart from the Sikorsky S-92 and Colombia 234 Chinook LR. The necessity for a rear loading ramp eliminated all small fixed-wing aircraft apart from four candidate aircraft.

The Sikorsky S92 was chosen over the Colombia 234 Chinook LR based on the S-92's certification in both the United States and Europe, while the Chinook is only type certified in the United States.

The Casa 212 was chosen over the three alternative small fixed-wing aircraft based on better commercial availability, as well as manufacture and history of use in Europe. None of the four small candidate aircraft are type certified in Europe.

4.2.1 Casa 212

4.2.1.1 Casa 212 Aircraft Overview

The CASA 212 is a light military transport aircraft that was designed to operate in areas lacking in infrastructure and unpaved runways. It has a high-wing configuration and fixed landing gear, is fitted with twin turboprop engines, and has excellent Short Take Off and Landing (STOL) capability.

The cargo compartment can accommodate 18 passengers and their luggage, or 16 fully-equipped paratroopers, or 4,409 pounds (2,000kg) of diversified cargo. A rear loading ramp enables different logistic transport tasks to be carried out. It can be opened while on the ground, to load and unload, or in flight for the airdropping of cargo, survival equipment or paratroops.

4.2.1.2 *Casa 212 Range Versus Payload Calculations*

Base Design, 2x150 Gallon Gelled Fuel Tanks, Estimated Kit Weight 1,100lbs:

Casa 212	**Data**	**Notes**
Maximum Gross or Max TO Weight:	16,796	From TCDS
Aircraft Decreased Fuel Capacity	3,240	Decreased to Maximize Gel Capacity
Empty Weight	8,800	From Mfr. Data
Crew (3@220 LBS)	660	
WP Gel Pump/Igniter System (Est.)	1,100	
Payload Available for Gel Fuel	2,996	= GW minus fuel, crew, EW & pump
Calculated Gel Fuel (gallons)	300	=Payload Wt. divided by 10
Gel Fuel Quantity (Lesser of calc amount or 300 gal)	**300**	MIN Function picks lesser value
Loiter Time (Hours)	0.30	@1000gph, Used in Range Calc.
Fuel Burn (LB/Hr)	800	From Mfr. Data
Total Duration at Full Fuel (Hours)	4.05	=Fuel Capacity/Fuel Burn Rate
Cruise Duration after subtracting Loiter	3.75	=Total Duration minus Loiter Time
Cruise Speed (Kts)	150	From Mfr. Data
Cruise Range	563	=Cruise Duration x Speed
Range /2 (Out & Back)	**281**	=Cruise Range / 2

Enhanced Design, 3x150 Gallon Gelled Fuel Tanks, Estimated Kit Weight 1,275lbs:

Casa 212	**Data**	**Notes**
Maximum Gross or Max TO Weight:	16,796	From TCDS
Aircraft Decreased Fuel Capacity	1,560	Decreased to Maximize Gel Capacity
Empty Weight	8,800	From Mfr. Data
Crew (3@220 LBS)	660	
WP Gel Pump/Igniter System (Est.)	1,275	
Payload Available for Gel Fuel	4,501	= GW minus fuel, crew, EW & pump
Calculated Gel Fuel (gallons)	450	=Payload Wt. divided by 10
Gel Fuel Quantity (Lesser of calc amount or 450 gal)	**450**	MIN Function picks lesser value
Loiter Time (Hours)	0.45	@1000gph, Used in Range Calc.
Fuel Burn (LB/Hr)	800	From Mfr. Data
Total Duration at Full Fuel (Hours)	1.95	=Fuel Capacity/Fuel Burn Rate
Cruise Duration after subtracting Loiter	1.50	=Total Duration minus Loiter Time
Cruise Speed (Kts)	150	From Mfr. Data
Cruise Range	225	=Cruise Duration x Speed
Range /2 (Out & Back)	**113**	=Cruise Range / 2

4.2.2 *Sikorsky S-92*

4.2.2.1 *S-92 Aircraft Overview*

The Sikorsky S-92 helicopter has become the industry's standard with a best-in-class safety record. The S-92 was certified to FAA/EASA harmonized Part 29 requirements, as amended through Amendment 47. It led the way by being the first aircraft certified to this rigorous standard and by meeting or exceeding oil and gas industry requirements. The S-92 incorporates state-of-the-art technology such as active vibration control, composite blades, and a long list of advanced safety features. A rear loading ramp enables different logistic transport tasks to be carried out.

4.2.2.2 *S-92 Range Versus Payload Calculations*

Base Design, 2x150 Gallon Gelled Fuel Tanks, Estimated Kit Weight 1,100lbs:

Sikorsky S-92	Data	Notes
Maximum Gross or Max TO Weight:	26,500	From TCDS
Aircraft Max Fuel Capacity	3,850	From Mfr. Data
Empty Weight	15,060	From Mfr. Data
Crew (3@220 LBS)	660	
WP Gel Pump/Igniter System (Est.)	1,100	
Payload Available for Gel Fuel	5,830	= GW minus fuel, crew, EW & pump
Calculated Gel Fuel (gallons)	583	=Payload Wt. divided by 10
Gel Fuel Quantity (Lesser of calc amount or 300 gal)	**300**	MIN Function picks lesser value
Loiter Time (Hours)	0.30	@1000gph, Used in Range Calc.
Fuel Burn (LB/Hr)	1,058	From Mfr. Data
Total Duration at Full Fuel (Hours)	3.64	=Fuel Capacity/Fuel Burn Rate
Cruise Duration after subtracting Loiter	3.34	=Total Duration minus Loiter Time
Cruise Speed (Kts)	130	From Mfr. Data
Cruise Range	434	=Cruise Duration x Speed
Range /2 (Out & Back)	**217**	=Cruise Range / 2

Enhanced Design, 3x150 Gallon Gelled Fuel Tanks, Estimated Kit Weight 1,275lb

Sikorsky S-92	**Data**	**Notes**
Maximum Gross or Max TO Weight:	26,500	From TCDS
Aircraft Max Fuel Capacity	3,850	From Mfr. Data
Empty Weight	15,060	From Mfr. Data
Crew (3@220 LBS)	660	
WP Gel Pump/Igniter System (Est.)	1,275	
Payload Available for Gel Fuel	5,655	= GW minus fuel, crew, EW & pump
Calculated Gel Fuel (gallons)	566	=Payload Wt. divided by 10
Gel Fuel Quantity (Lesser of calc amount or 450 gal)	**450**	MIN Function picks lesser value
Loiter Time (Hours)	0.45	@1000gph, Used in Range Calc.
Fuel Burn (LB/Hr)	1,058	From Mfr. Data
Total Duration at Full Fuel (Hours)	3.64	=Fuel Capacity/Fuel Burn Rate
Cruise Duration after subtracting Loiter	3.19	=Total Duration minus Loiter Time
Cruise Speed (Kts)	130	From Mfr. Data
Cruise Range	415	=Cruise Duration x Speed
Range /2 (Out & Back)	**207**	=Cruise Range / 2

4.2.3 Recommendation: Discussion of Casa 212 Versus Sikorsky S-92

As discussed above, the Casa 212 and Sikorsky S-92 could both meet operational and design requirements for a long-range ISB mission. Additional considerations should include range versus gelled fuel quantity, the different handling characteristics of fixed-wing aircraft versus rotorcraft, as well as cost. The superiority of the Casa 212 versus Sikorsky 212 depends on how these considerations are prioritized for the mission.

The base system design includes 2 x 150-gallon fuel tanks for transporting the gelled fuel. With the base design, the Casa 212 has superior range of 281 miles (562 out and back). The S-92 range is 217 miles under the base system design (434 out and back). Under the base design, the Casa 212 is the superior aircraft if range is prioritized for the mission.

Maximizing gelled fuel quantity is an important criterion for a long range ISB mission. To that end, additional fuel tanks may be added to the base design to increase gelled fuel quantity to 450 gallons (3 x 150 gallons). With the addition of one 150-gallon tank, the increased weight significantly decreases the range of the Casa 212 to 113 miles (226 out and back), by decreasing the available fuel capacity. With higher payload availability, the S-92 maintains a range of 207 miles (414 out and back). If maximizing gelled fuel quantity, while maintaining long range, is prioritized for the mission, the S-92 is the superior aircraft.

The handling characteristics of rotorcraft are proven effective in safely and reliably carrying out ISB operations. Rotorcraft have superior maneuverability to fixed-wing aircraft, with no minimum speed restrictions. These characteristics are important for operational safety in poor visibility conditions and also for positive identification of oiled melt pools. Rotorcraft are also capable of landing without the need for an airstrip, allowing for operations closer to oil spill locations. By contrast, the minimum safe low level operating speed for fixed-wing aircraft, including the Casa 212, could negatively impact operations, by hindering positive identification of oiled melt pools, especially during periods of low contrast light levels.

Lastly, the Sikorsky S-92 is a more expensive aircraft than the Casa 212. There are several options for aircraft acquisition, including: purchasing a dedicated aircraft; long-term lease; or charter. The cost of each option will vary depending on the specific agreement and circumstances. Estimated purchase price for a Sikorsky S-92 is approximately 17 million base price, while purchase of a Casa 212 is approximately 8 million. Charter rate for the Sikorsky is approximately $5,000/blade hour, while the Casa 212 is approximately $2,500/blade hour.

5. CONCEPTUAL DESIGN OF DISTRIBUTION AND IGNITION SYSTEM

5.1 Design Overview

The proposed system is divided into four major sub-systems:

1. Gel Fuel Storage and Pumping – Consisting of a storage tank, pump, plumbing and heat blankets.
2. Ignition System –The design includes a simple spark ignition system, piezoelectric or electrode, aircraft grade. The ignition device allows for portable ignition, without the need for propane, by relying on the mechanical generation of a spark to ignite the gelled fuel.
3. Hose and Drogue Chute Assembly – Necessary to allow dispensing of the ignited gel fuel at a suitable distance aft of the aircraft to ensure no fuel swirls around and returns to any airframe area.
4. Control System – Presents status and control of the dispensing system, and necessary auxiliary systems such as fire detection and extinguishing. Functions will include level sense & display, ground fill operations, and control of the pump and valves.

5.2 Major Sub-Systems Design

5.2.1 Gel Fuel Storage and Pumping

Gel Tank – The tank will be of double wall construction with integral sloped bottom and sump to maximize useful volume. The tank must be leak proof and vapor tight, and must, in a 9g event (the FAA euphemism for "crash"), remain constrained in place on the aircraft, without breaks or leaks. The secondary containment construction must also be vapor tight, but may rely on the tank structure for support. The tank will be designed to enable refilling while inside the aircraft. Heat blankets will be utilized to keep the gel temperature at 40-50° F.

Pump –The design includes an electric motor-driven pump, using available aircraft auxiliary power. High viscosity fluids are best propelled via positive displacement pumps. A peristaltic pump is recommended because it offers positive flow, yet isolates the fuel from the pump material. This creates a much easier-to-maintain pump system, reduces the chance of fuel contamination, and is easier to clean up after use. The "wetted areas" of the pump (the soft tubing running through the pump rollers) will require secondary containment. To accomplish this, the entire pump/motor assembly will be enclosed.

Plumbing – The use of aerospace approved double-wall piping will be utilized as standard equipment throughout this system. All plumbing will be stainless steel to meet aircraft fire ratings, and sized for optimal fluid delivery. Interconnections between pallets will be of a "quick disconnect" design to ease installation in the host aircraft.

5.2.2 Ignition System

Plumbing –Aerospace approved double-wall piping will be utilized as standard equipment throughout this system. See notes above regarding gel fuel plumbing.

Ignitor – The design includes a simple spark ignitor system, piezoelectric or electrode, aircraft grade. The spark ignitors will allow for generation of spark as the gelled fuel exits the hose and chute assembly. This system operates on aircraft 28VDC power, and is controlled from the cockpit (see "Control System").

5.2.3 Hose and Drogue Chute Assembly

Dispensing of Burning Gel Fuel globules must be accomplished well away from the aircraft structure, and well outside of turbulent air surrounding an aircraft in flight. The design includes "off-the-shelf" aerial refueling technology to install a hose reel fitted with a drogue chute. Modification as necessary of an existing system will save time and money, and offer a tested, robust solution.

Reel – A motor-operated reel allows remote deployment and retrieval of the hose/drogue assembly.

Hose – The hoses in use in modern aerial refueling systems are strong enough to withstand the tensile load of the drogue. The preliminary design includes the use of existing hoses as a "carrier" containing gel fuel line and electrical cables.

Chute – Existing chute designs may be adapted for our use. The biggest design consideration is adaptation of the chute to accommodate the bulk and weight of our large discharge canister versus the planned airspeed/airflow over the chute.

5.2.4 Control System

The control system architecture will be based on simple, reliable switch, diode and relay logic. The benefits include ease of certification, simple troubleshooting in the event of a malfunction, and readily available components for initial build and future maintenance. Control of the system will be entirely accomplished from a cockpit control panel, portable or permanently installed. Fire detection and extinguishing will be required, and required to meet FAA standards for function and control panel location (within a defined pilot field of view). For this reason, fire detection and extinguishing may be separated from normal system control equipment.

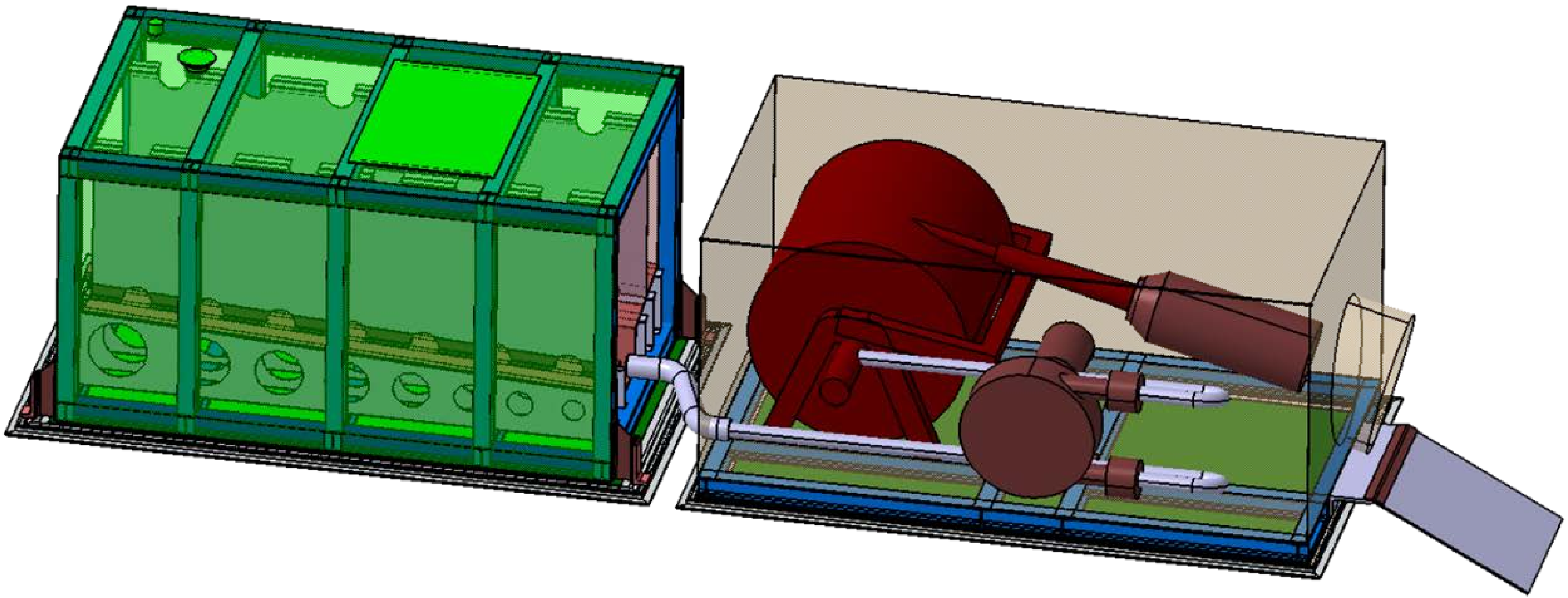
5.3 System Weight

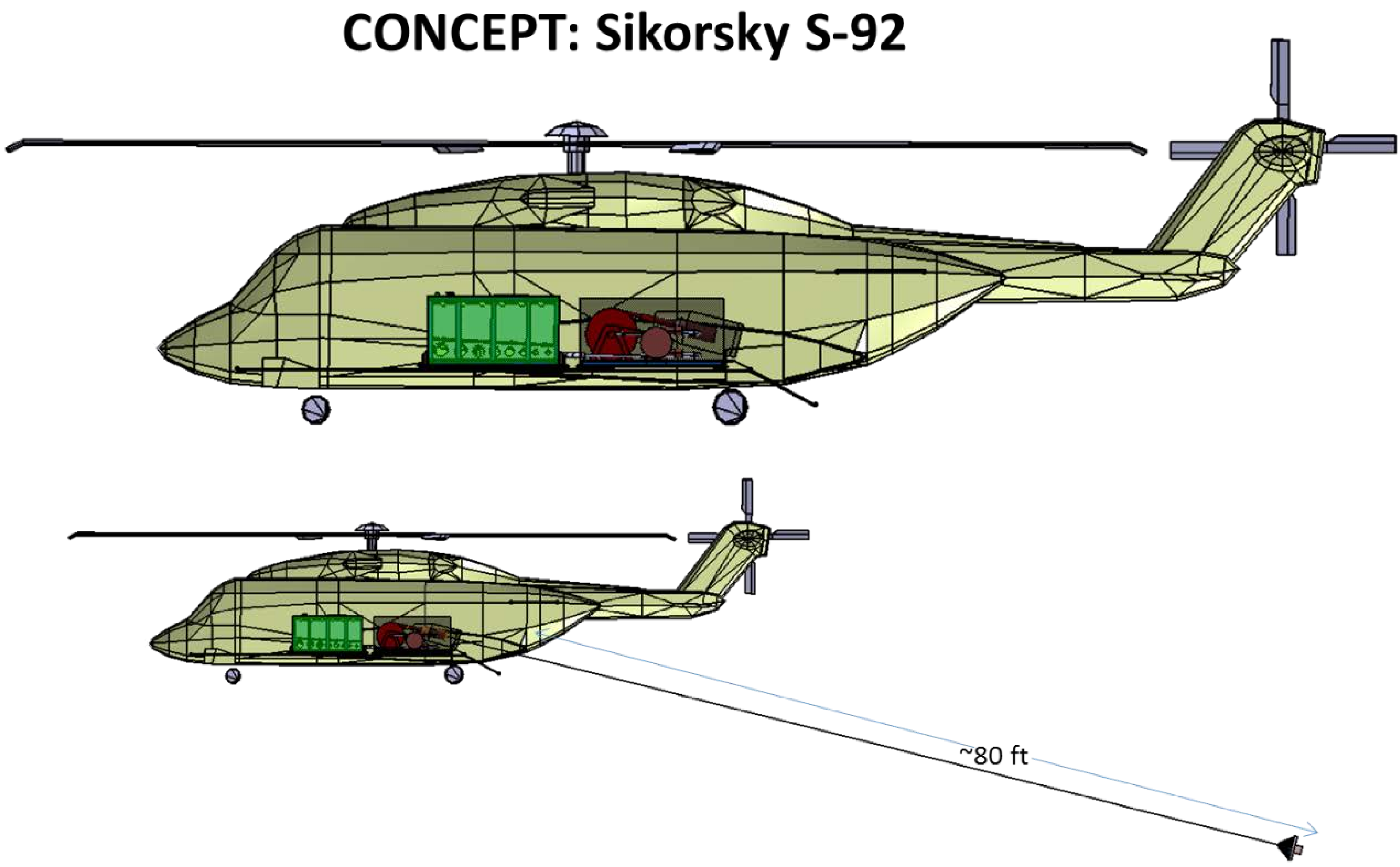
Following is the estimated system weight breakdown based on the conceptual design:

Double walled fuel tanks (2x150 US Gallons, valves, plumbing and pallet)	400 lbs
Pump and Electric Motor	100 lbs
Hose and reel (Ignitor and Drogue)	450 lbs
Misc. Equipment (Control System, Tie-Down Hardware, etc.)	150 lbs
Total Basic System:	**1100 lbs**
Extra Gelled Fuel Tank-150 US Gallons (per additional tank)	175 lbs

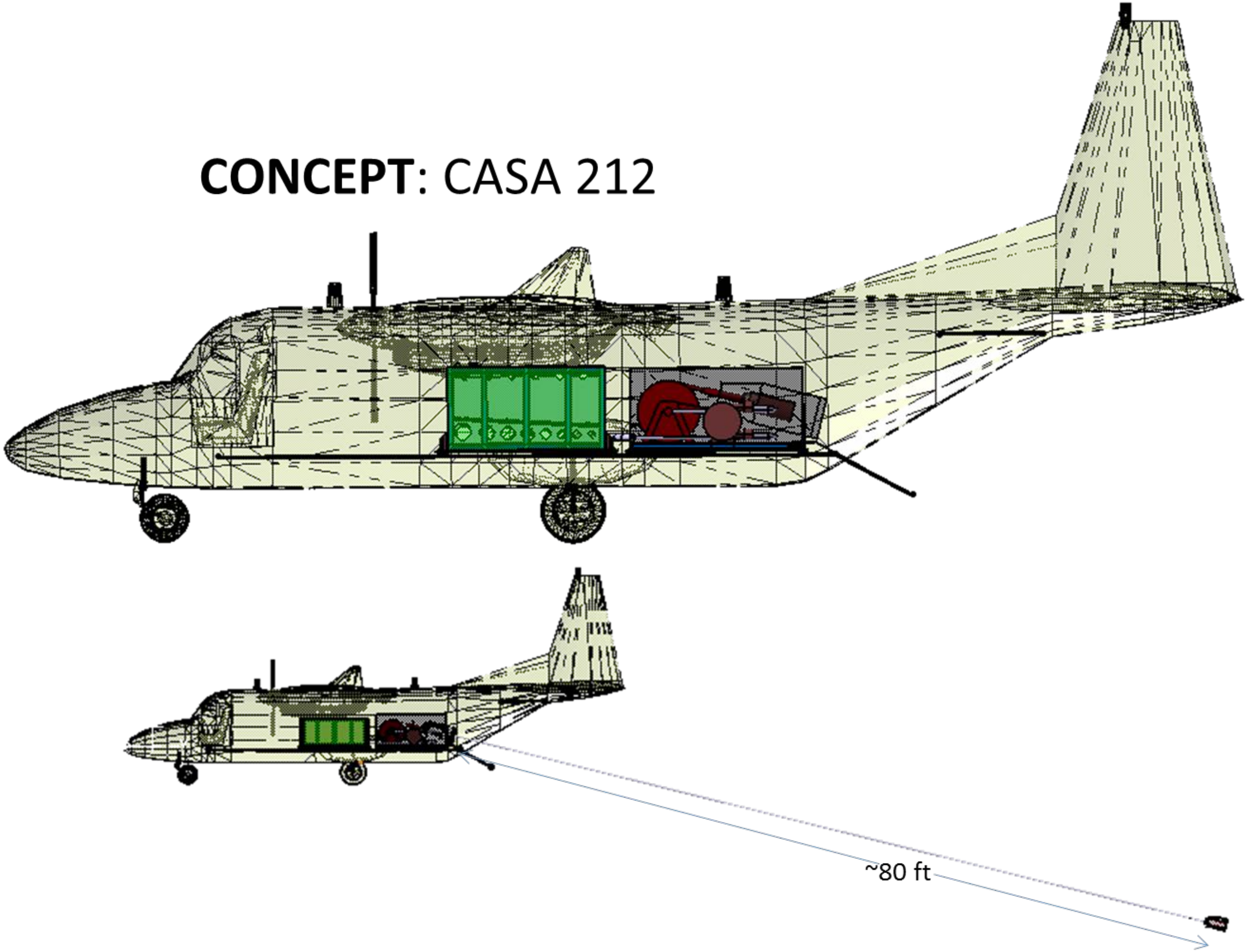
5.4 Conceptual Design Drawings

OVERVIEW: AIRBORNE DELIVERY KIT

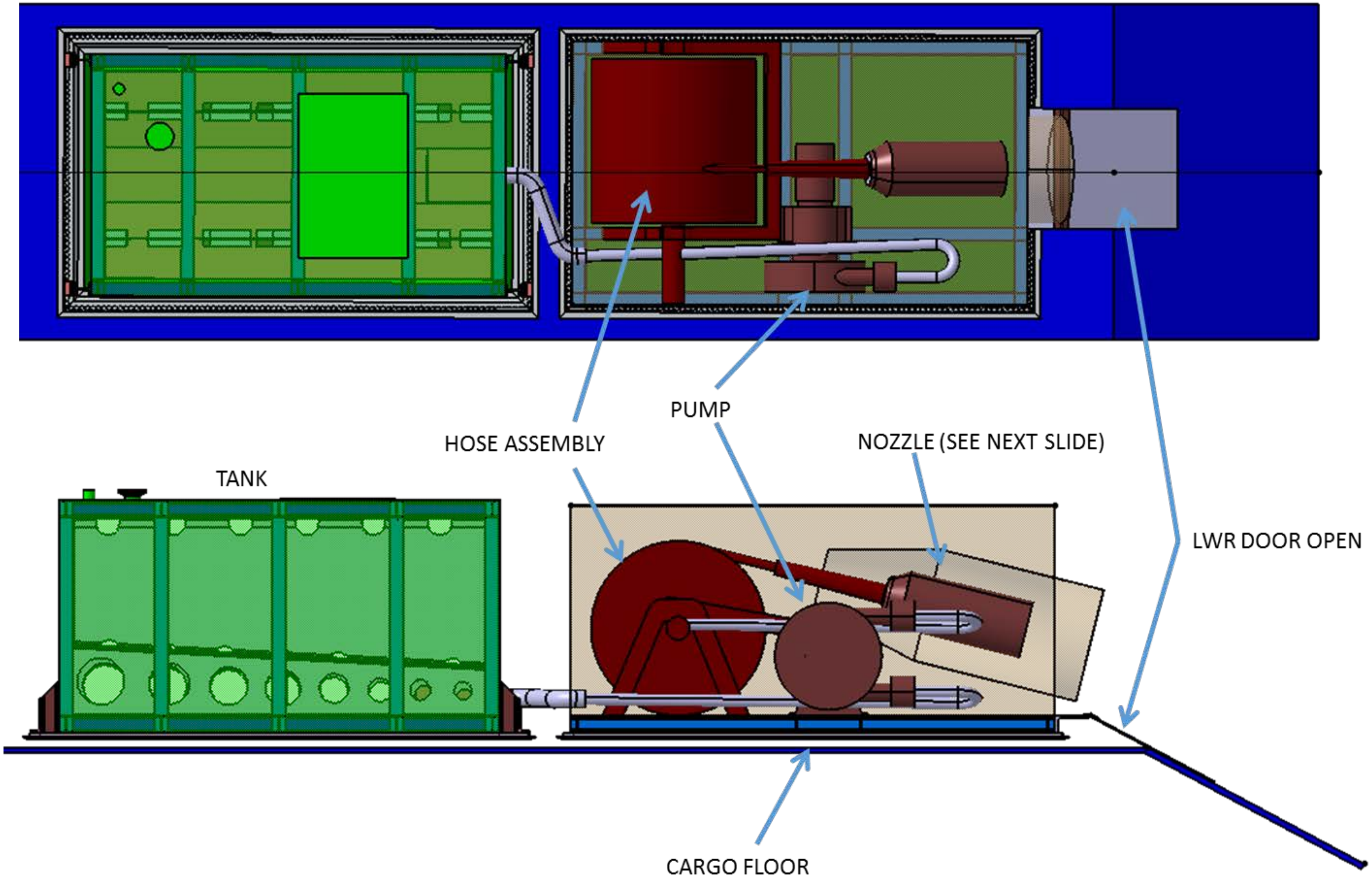


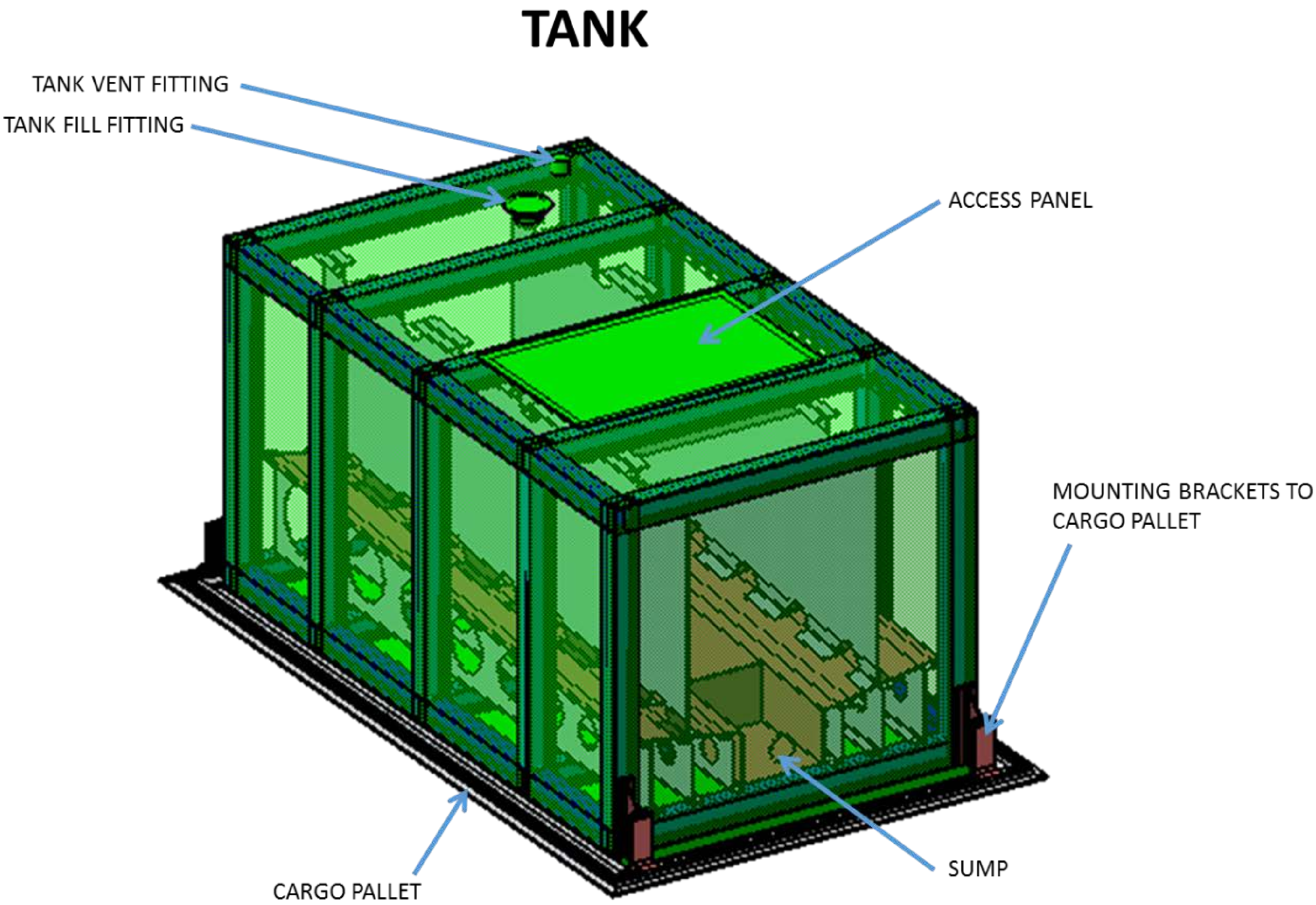

CONCEPT: Sikorsky S-92
~80 ft

CONCEPT: CASA 212

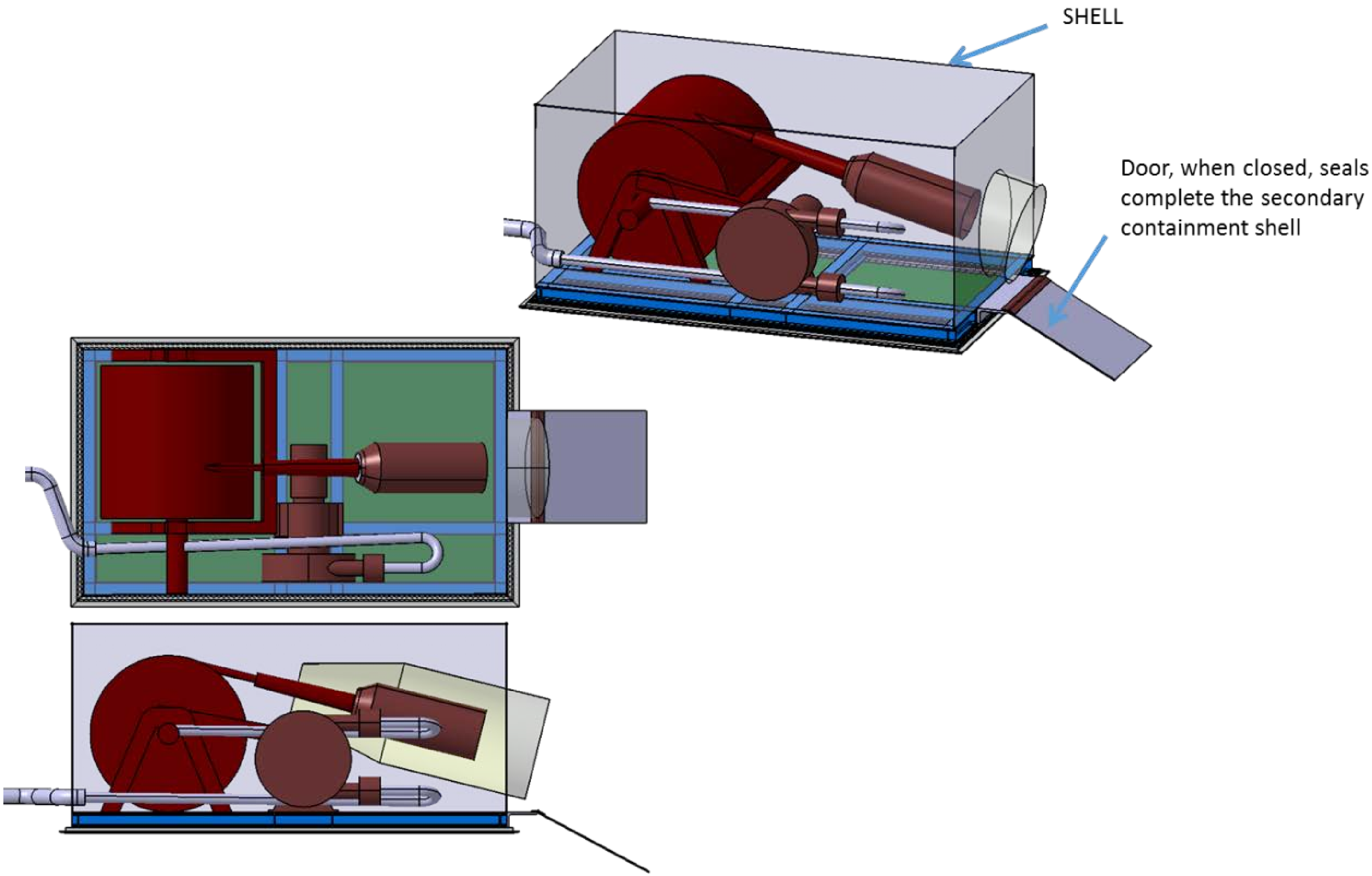


DETAILED DESCRIPTION



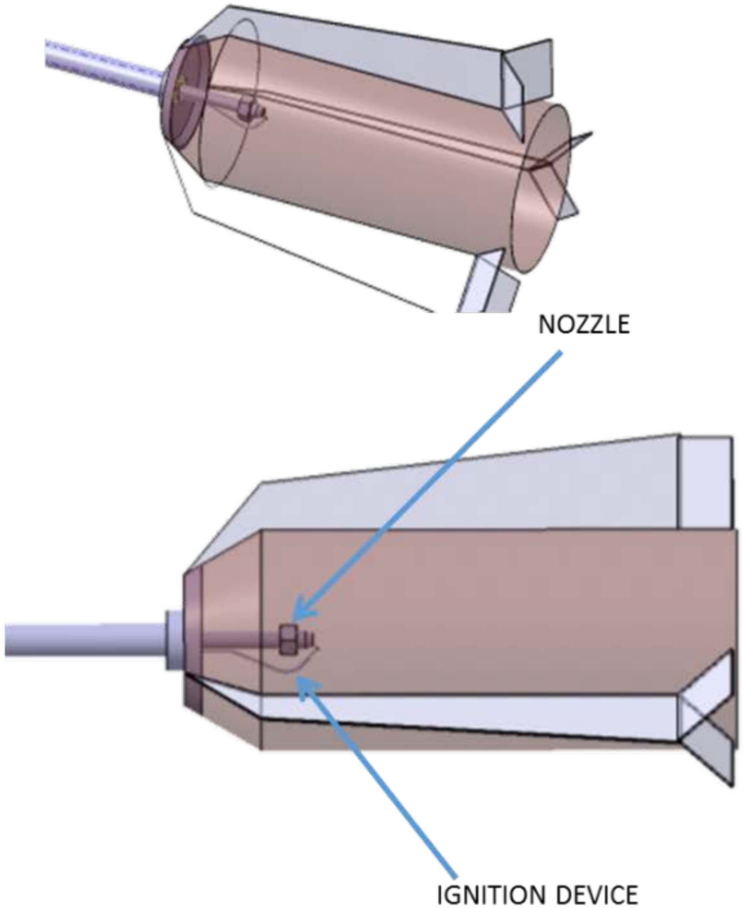

TANK
TANK VENT FITTING
TANK FILL FITTING
ACCESS PANEL
MOUNTING BRACKETS TO CARGO PALLET
SUMP
CARGO PALLET

PUMP AND DROGUE



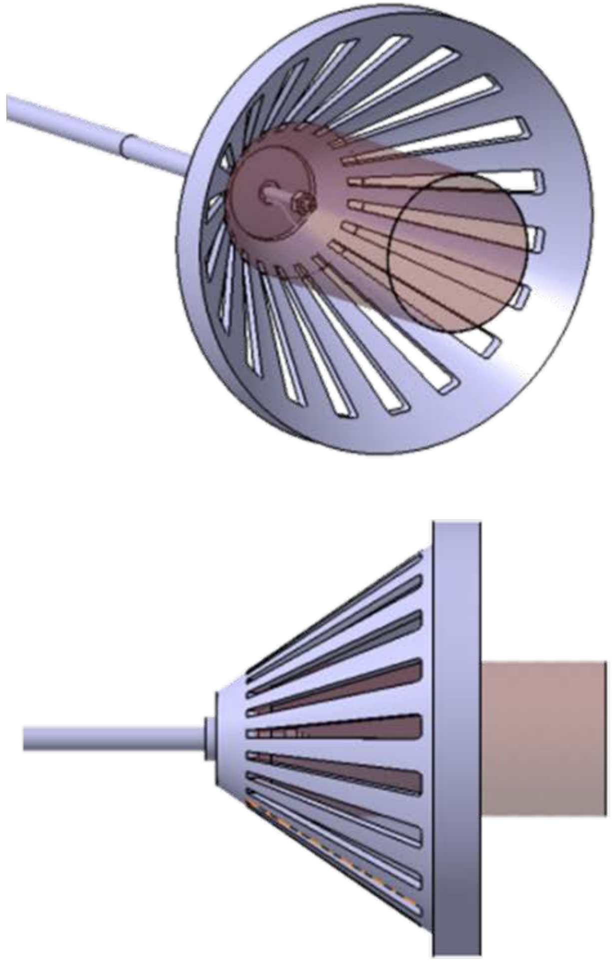
TWO OPTIONS: NOZZLE ASSEMBLY IN-FLIGHT

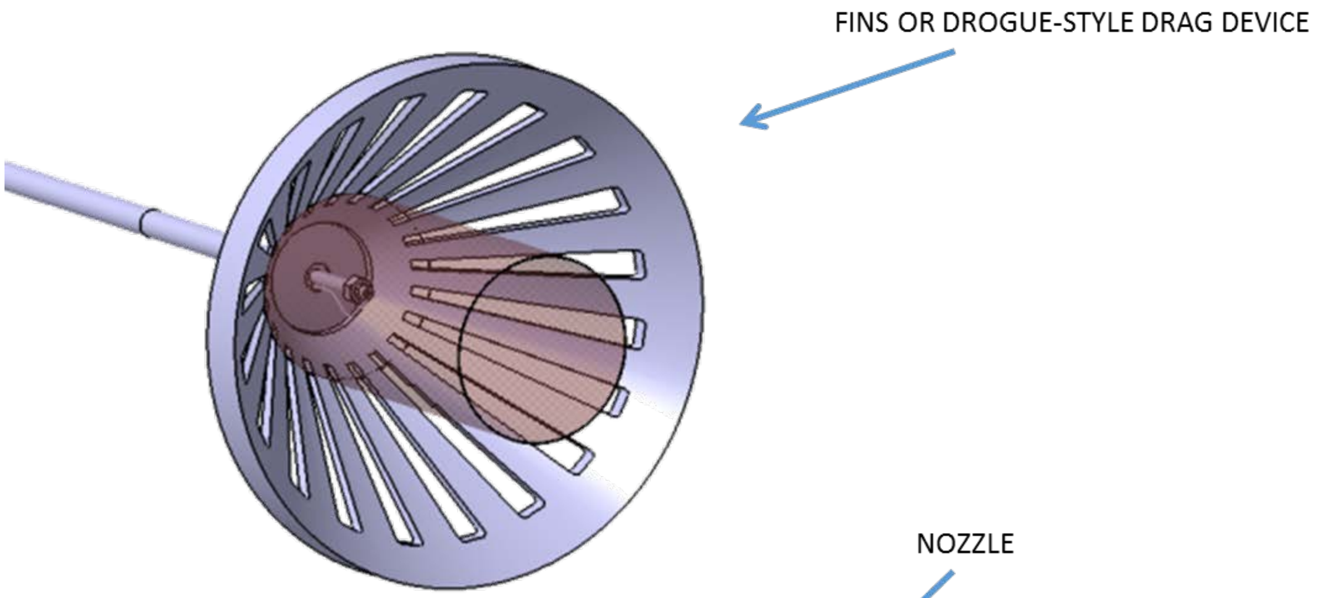
FINS

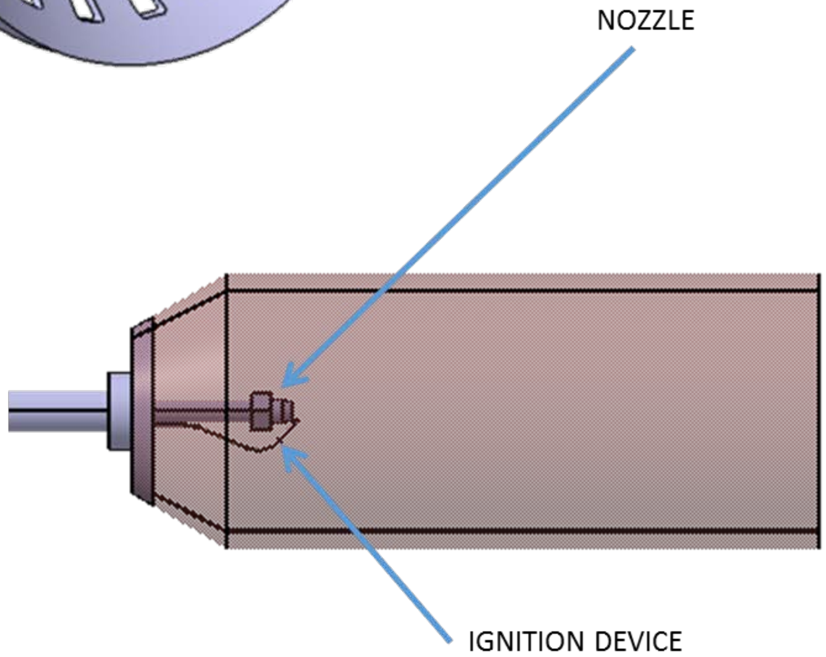


DROGUE

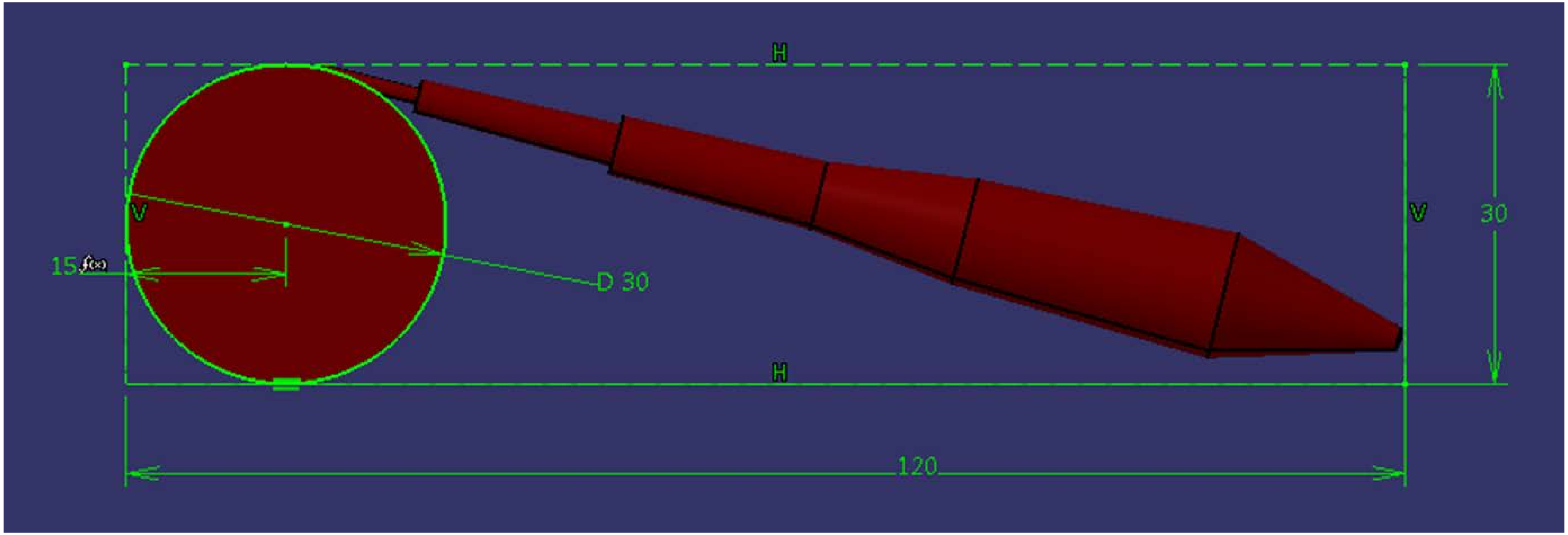
SIMILAR IN SIZE TO COBHAM ADV DROGUE



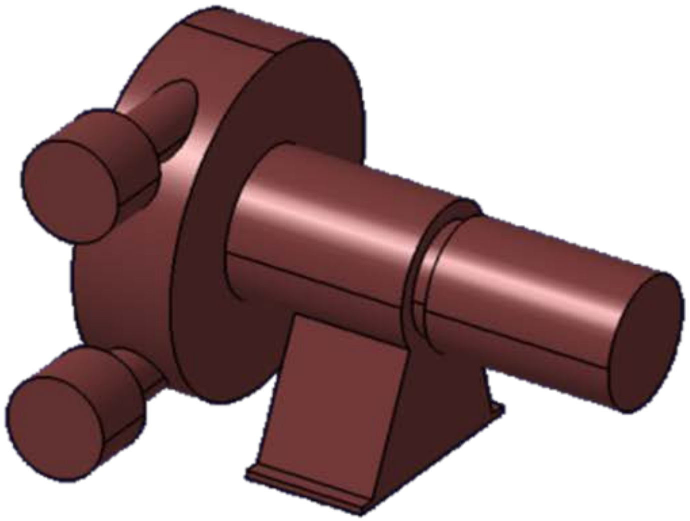

FINS OR DROGUE-STYLE DRAG DEVICE


NOZZLE
IGNITION DEVICE

REFUELING ASSEMBLY SIZING



PUMP SIZING



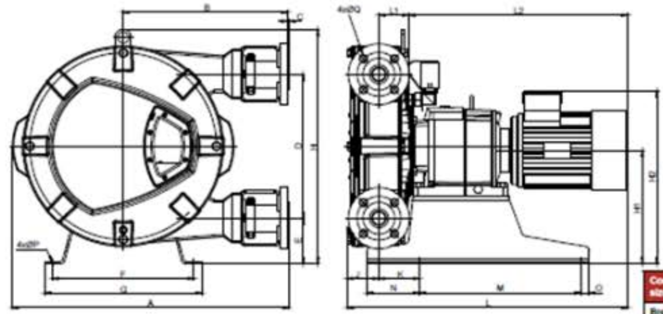
Bredel 25, and Bredel 32 hose pumps

Bredel SERIES
Bredel Hose Pumps

FEATURES AND BENEFITS

- Sealless, valveless pumping principle for reliable, low maintenance metering, dosing and transfer
- Flow rates up to 5,250 L/hr (23.1 USGPM) and pressures up to 16bar (232 psi)
- Dry running and self-priming, with up to 9.5 meters (30 foot) suction lift capability
- Robust design for aggressive chemicals or abrasives
- Compact direct coupled design to maximise gearbox life
- Simple hose change decreases cost of ownership, downtime and need for parts inventory

DIMENSIONS



Connector sizes	ANSI 150#	EN DIN	JIS
Bredel 25	1"	25mm	25mm
Bredel 32	1.5"	40mm	40mm

Type	A	B	C	D	E	F	G	H	H1	H2max	J	K	Lmax	L1	L2max	M	N	O	ØP	ØQ	R
Bredel 25 (mm)	521	304	2.5	264	98	279	315	460	222	359	66	97	592	58	468	305	120	15	12	14	85
Bredel 25 (inches)	20.5	12	0.09	10.4	3.9	11	12.4	18.1	8.7	14.1	2.6	3.8	23.3	2.3	18.4	12	4.7	0.6	0.47	0.6	3.3
Bredel 32 (mm)	631	375	2.5	330	105	324	360	538	260	402	72	93	684	68	544	370	120	20	12	18	100
Bredel 32 (inches)	24.8	14.8	0.09	13	4.1	12.8	14.2	21.2	10.2	15.8	2.8	3.7	26.9	2.7	21.4	14.6	4.7	0.79	0.47	0.71	3.94

TECHNICAL SPECIFICATIONS

	Bredel 25	Bredel 32
Flow range	up to 2,880 L/hr (12.7 USGPM)	up to 5,250 L/hr (23.1 USGPM)
Capacity	0.300 L/rev (0.079 G/rev)	0.625 L/rev (0.165 G/rev)
Minimum starting torque	115Nm (1018 inch-lbs)	210Nm (1859 inch-lbs)
Hose lubricant required	2 litres (0.53 USG)	3.5 litres (0.92 USG)
Pumphead weight	39kg (85.98lbs)	58.5kg (128.97lbs)
Max inlet pressure	3.5 bar abs (51 psia)	3.0 bar abs (44 psia)
Common features		
Suction pressure	0.05bar abs (0.73 psia)	
Maximum discharge pressure	1600 kPa (16 bar) (232psi)	
Product temperature range*	-10C up to 80C (14F up to 176F)	
Ambient temperature range**	-20C up to 45C (-4F up to 113F)	

5.5 Minimum Design Temperature

From experience with three large-scale oil under ice spills in the mid 70's and early 80's in the Canadian Beaufort Sea (climate very similar to Barrow Alaska) trapped oil first appeared on the ice surface in any significant amount in late May. This corresponds with the date when the average long term daily maximum reaches 32°F at about 70-71° N in the Canadian or US Arctic - May 28. Most record minimum temperature records in this region were set in the period 1920 to 1950. Over the past thirty years, the onset of thawing has shifted to earlier in May. Advancing the earliest date when visible oil could appear on the ice by 10 days from May 28 to May 18 is a reasonable way to account for the documented effects of temperature change. Looking at this date over the past 20 years, the record daily minimum temperature was +4°F set in 2013. The next three coldest May 18 days occurred in 2000, 2001 and 2007 at +6, +9 and +10 respectively. Every other May 18 in that 20-year period was +14F or above. On this basis, +4°F (-15°C) was selected as a conservative minimum operating temperature for the Alaskan Beaufort or North Chukchi Sea offshore at the 5% exceedance level (1 year in 20 might be colder based on the modern record).

A similar approach was taken to evaluate a realistic minimum operating temperature for Svalbard (Longyearbyen) in the Norwegian Barents Sea. The temperature record for this station is already focused on the past 20 years so no further adjustment was made for temperature change. The date with the mean daily maximum of ≥32 on Svalbard is May 26. Only one field experiment looked at oil surfacing through the ice on Svalbard (2006). In that case, 67% of the oil was estimated to have surfaced by May 10. It turns out that the winter chosen for the spill was one of the warmest in recent history. First significant oil appeared by April 29 (15%) with daily maximum air temperatures of 43°F - 20 degrees above the average for that date. This pattern continued with 67% of the oil up by May 10 and the daily max temperatures of 35°F, still 12 degrees above normal. If the "normal" system operating window in this part of the world is considered to start May 26, then the recommended minimum operating temperature for the Norwegian Barents Sea from 1996-2016 records is +21°F (-6°C).

Source: Weather Underground temperature archives for Barrow AK and Longyearbyen Svalbard – analyzed by JIP ISB Technical Working Group member, D. Dickins.

5.6 Fixed-Wing Aircraft Aerial Igniter Calculations

The basis of these calculations is a CASA 212 aircraft capable of flying at 100 mph (87 knots) carrying 1250 L (331 gallons) of warm gelled fuel.

Previous ground-based experiments (Preli et al., 2011; Ybarra, 2015) with modified Helitorch ignition systems proposed for fixed-wing aircraft have shown that it is possible to produce burning blobs of gelled fuel (100% Aviation gasoline) in winds of up to 110 mph, providing the gelled gasoline was kept relatively warm (5 to 10°C, 40 to 50°F) up to the point of atomization and ignition. Gelled gas pump rates of 57 L/min (15 gpm) through an 11 mm (7/16th inch) shrouded ignition system nozzle resulted in successful ignition of the gelled gas and sustained burning of individual gel blobs after release. One prototype igniter system tested involved ignition of the gelled gas using an electrode system, without the need for a propane or liquid fuel pilot flame, which offers significant advantages when planning to install the system in an aircraft.

The electrode-based ignition system would also lend itself to installation at the end of a flexible hose/electrical cable bundle trailed behind the aircraft.

Assuming each gelled gas blob is about 4 cm in diameter, comprising about 34 cm^3 (1 fl. ounce), the burning blobs would decelerate once released from the aircraft to fall at their terminal velocity of 25 m/s (55 mph), Assuming the aircraft is flying at an altitude of 30 m (100 ft) the burning gel igniters would hit the surface in about 2.5 seconds. A flowrate of 57 L/min (15 gpm) produces approximately 1700 blobs per minute at an airspeed of 87 knots (2680 m/min) this results in one blob for every 1.6 m of forward travel.

Based on field trials (Masters et al., 1986) with a Helitorch flying at 35 knots (40 mph) at altitudes of 45 to 60 m (150 to 200 feet) the gelled blobs would spread out laterally as they fall to cover a swath of approximately 5 m width by the time they hit the surface. Thus, a fixed-wing system with one nozzle igniter would generate a trail of burning gelled gasoline blobs on the ice surface 5 m wide with one gelled blob every 1.6 m, equivalent to one gelled blob every 8 m^2.

A CASA 212 with a full load of 1250 L (331 gal) of gelled gasoline would have 22 minutes of gelled fuel available and could create 37,000 individual ignition points in a narrow strip 55 km (34 miles) long. Multiple passes and sorties would be required to achieve ignition of the oil in melt pools in the above-noted scenario.

6. SUMMARY OF THE FEDERAL AVIATION ADMINISTRATION (FAA)/EUROPEAN AVIATION SAFETY AGENCY (EASA) CERTIFICATION PROCESS

The proposed long-range aerial ignition system would be certified with the FAA/EASA through application for a Supplemental Type Certificate (STC). An STC is a type certificate (TC) issued when an applicant has received FAA/EASA approval to modify an aeronautical product from its original design. The STC approves not only the modification but also how that modification affects the original design.

FAA/EASA Bilateral Aviation Safety Agreement

Obtaining both an FAA STC and EASA STC for an aeronautical product, increases the ability to utilize and market the product worldwide. Concurrent certification is recommended to take advantage of cost and time savings afforded by the bilateral agreement in place between the United States and the European Union ("Agreement Between the United States of America and the European Community on Cooperation in the Regulation of Civil Aviation Safety"). Concurrent validation by EASA, also allows any unique EASA certification requirements or concerns to be addressed in the design and development phase of a product. The "Technical Implementation Procedures for Airworthiness and Environmental Certification (TIP) - Revision 5 (Sept. 15, 2015)," sets forth the procedures for achieving EASA validation of an FAA issued STC. The level of review by EASA of the data supporting the FAA STC is dependent on the safety risks presented by the STC. In general, even with a non-basic STC requiring heightened scrutiny by EASA, as would be the case with the proposed ISB system, there will be substantial time and cost savings with concurrent validation.

Supplemental Type Certificate (STC) Project Prioritization

The FAA has limited resources. They allocate those resources based on safety risk. The FAA Project Prioritization process helps them allocate their resources on airplane certification projects. Based on the applicant's certification team of experienced FAA Designated Engineering Representatives (DERs)/Designated Airworthiness Representatives (DARs), the FAA may retain fewer compliance findings. The Applicant can help the FAA by being thorough in the development of the Project Specific Certification Plan (PSCP) as well as submitting quality documents in time frames agreed to in the PSCP. See further discussion about the PSCP below. As the FAA gains confidence in the applicant's certification team's experience, the FAA may be able to delegate more findings of compliance.

FAA Project Classification and Oversight

FAA classifies a project to determine the level of FAA oversight and participation. They determine whether the project is "significant or non-significant" as defined in FAA Agency directives. The classification helps the FAA Aircraft Certification Office (ACO) identify related issues in the early stage of project planning.

STC Application Process

FAA Form 8110-12, Application for STC, the draft PSCP and Conformity Inspection Plan (CIP) and the Applicant submittal letter are the basis for initiating the FAA STC Project. Application acceptance by FAA and familiarization kickoff meeting between Applicant team (DERs/DARs) and FAA engineering team members initiates the project.

Applicant and FAA Project Teams

The Applicant certification team is comprised of DERs specializing in Structures, Systems and Equipment –Electrical and Mechanical, Power plant, Flight Test and Cabin Safety. The FAA certification project team is the working level group at the FAA ACO that works with the Applicant, conducts the certification process, and makes the finding of compliance. FAA provides a project manager, technical specialists, test pilots/engineers, Manufacturer Inspection District Office (MIDO) inspectors and operations/airworthiness inspectors from the Aircraft Evaluation Group (AEG).

Project Specific Certification Plan (PSCP)

The PSCP is the primary project management tool for coordinating activities between the FAA and the Applicant to implement the techniques and compliance requirements. While filling out the Compliance Checklist (CCL), it must be decided which 14 CFR Part 25 regulations need to have compliance shown based on the type of airplane product change, modification or alternation. It also needs to be decided on how regulatory compliance will be shown (Design, Analysis, Test, Other, etc.) and who needs to approve or recommend approval by the Applicant's DERs and DARs. Revisions to the PSCP will be done throughout the life of the project as issues arise.

Issue Papers

Unsafe features or characteristics that surface during the project will be addressed and resolved by the Applicant and FAA using Issue Papers. The Applicant can submit an Applicant Statement in support of an Issue Paper to the FAA-ACO assigned to the project. Typically, projects that involve flammable fluids will automatically require what is called the G-1 Issue Paper (I/P). Additionally, there is the F-1 Issue Paper that for instance addresses the flight test regulation, 14 CFR Part 25.251, Vibration and Buffeting. This requirement requires both flight test and Computational Fluid Dynamic (CFD) analysis. Issue Papers are further addressed by both FAA Policy Making and Regulatory Standards Group from FAA ACO, Seattle, WA for final approval.

Implementation Activities: Data Submittal and Acceptance

This phase in the certification process includes the overall basic steps for completing submittals and issuance of the STC.

- Data submittal for approval (drawings, test plans, reports, etc.)
- Certification Project Schedule
- Type design data and substantiating data (show compliance to certification basis)
- FAA design evaluation (based on Master Drawing List)
- Risk assessment including FHA (failure hazard analysis and SSA (systems safety analysis)
- Conformity inspections (parts, assemblies, installation and test setups)
- Applicant test plan(s) and FAA approval
- (Before witnessing) engineering ground and flight tests
- Engineering certification tests (DER witnessed)
- Engineering compliance inspection
- Detailed substantiation and stress analysis
- Experimental airworthiness certificate (issued by FAA DAR)
- Ground inspections, ground tests and flight tests
- Review of Applicant's flight test results
- Type Inspection Authorization (TIA)
- Flight test conformity inspections and certification flight tests (FAA/DER Pilots)
- Aircraft Evaluation Group (AEG) activities
- Aircraft Flight Manual Supplement

- Aircraft Weight and Balance Loading Report
- Instructions for Continued Airworthiness
- Issuance of Supplemental Type Certificate

Certification Project Schedule

The project schedule identifies the major milestones and scheduled deliveries. Every effort is made to assure realistic schedule. The following listing constitutes major schedule milestones:

- • Descriptive data submittal
- • Substantiating data submittal
- • Tests schedule, including TIA
- • Conformity inspections schedule
- • Compliance inspections schedule
- • Expected final approval

DER Approval Forms Used in the STC Certification Process

For the Master Drawing List with drawings, the FAA DER provides appropriate approval via FAA Form 8110-3, Statement of Compliance with Airworthiness Standards. FAA Form 8110-3 approvals are also required for analysis reports and company test reports for the following disciplines: Structures, Mechanical Systems, Electrical Systems, Flight Test, Powerplant and Cabin Safety.

Testing and Test Plan(s) Submittal and FAA Approval

Testing is required to demonstrate compliance with the applicable regulations. Test results from component, ground, and flight testing is typically required. Component, ground and flight testing demonstrate that the completed modification or installation complies with the applicable airworthiness standards. DER FAA Form 8110-3 recommend approval only applies to test plan submittals for structures, mechanical, electrical, power plant and cabin safety. The test plan(s) must show compliance to the regulations and approved by the FAA prior to beginning of any testing. FAA conformity inspection of test articles and test setup is necessary to ensure conformance to the engineering drawings and the test plan.

FAA Conformity Inspections

Conformity inspections verify and provide objective documentation that the test articles, parts, assemblies, installations, functions and test setups conform to the Applicant's design data for both quality assurance and engineering purposes. The FAA MIDO conformity inspection must be successfully accomplished before any certification ground or flight tests are conducted. Prior to doing any FAA conformity inspections, the Applicant must submit FAA Form 8130-9, Statement of Conformity. This Form attests that the drawings, articles conform to the proposed type design of the project. MIDO compliance inspection verifies that the modification meets the applicable airworthiness standards.

To facilitate the conformity inspection process, the FAA DER inputs the Request for Conformity (RFC) into the national database system called the National Automated Conformity Inspection Process (NACIP). Eventually, through the NACIP system, the conformity request gets delegated by MIDO to the FAA DAR assigned to the project. As soon as the DAR is delegated the conformity inspection can be performed. Note that all the FAA DAR provides FAA Form 8100-1, Conformity Inspection Record, to the ACO project manager and MIDO prior to any official certification ground or flight testing.

Furthermore, the DAR will issue the FAA Form 8130-3, Airworthiness Approval Tag, when completing the conformity inspections in order to be able to sell the conformed airworthiness parts and also to export the parts.

Type Inspection Authorization (TIA)

Before the FAA issues the TIA, a flight test risk management assessment must be performed by FAA flight test personnel. The signed FAA Form 8110-1, TIA, reflects adherence to FAA orders to ensure that the associated flight test risks are acceptable. The TIA is an internal FAA document. The TIA authorizes FAA manufacturing inspection to conduct conformity and airworthiness inspections, and authorizes FAA flight test to conduct flight inspections. Note that all inspections and tests called out for by the TIA are completed satisfactorily before FAA issues the STC. Testing requirements include submittals from flight, electrical, structural, systems, etc. The TIA is performed by FAA Flight Test Pilot and/or the FAA DER Test Pilot. All ground and flight testing approvals are completed by the appropriate FAA DER via FAA Form 8110-3 after the data is collected and completed in a final results test report.

Airplane Flight Manual Supplement (AFMS)

An aircraft alteration and/or modification that change the operating characteristics or procedures for safe operation will require including an Airplane Flight Manual Supplement (AFMS). The AFMS needs to match the format of the basic aircraft flight manual it is attached to. A draft airplane flight manual supplement is required before the FAA ACO issues the TIA.

Aircraft Evaluation Group (AEG)

AEG inspection represents the FAA Flight Standards Division. AEG operation inspectors evaluate flight crew operating manuals, manufacturers' flight training programs, and aircraft designs for both operational and manufacturing suitability. AEG examine the maintenance aspects of the STC project, and determine the acceptability of the Instructions for Continued Airworthiness (ICA).

Instructions for Continued Airworthiness (ICA)

The ICA contains an airworthiness and maintenance portion. FAA approves the airworthiness limitation section of the ICA. On the other hand, the AEG accepts the maintenance portion of the ICA. The ICA must include all necessary functions to keep the aircraft airworthy. This will include information such as troubleshooting, servicing, inspections, and functional checks.

Final Data Submittal

After completion of FAA compliance inspections and testing, submittal of all final data is to be made to the ACO project manager for review and approval. Final submittals will include items such as flight manual supplement, test reports, latest MDL and other technical manuals. All final data is assumed to be accurate, applicable and that any analysis does not violate the assumptions of the problem.

Statement of Compliance

The Statement of Compliance is a signed letter from the Applicant saying that they agree that all of the FAA airworthiness regulations have been complied with in accordance with the PSCP.

Issuance of FAA Approved Flight Manual Supplement

FAA will issue an approved airplane flight manual supplement prior to releasing the STC award.

<u>Issuance of Supplemental Type Certificate (STC)</u>

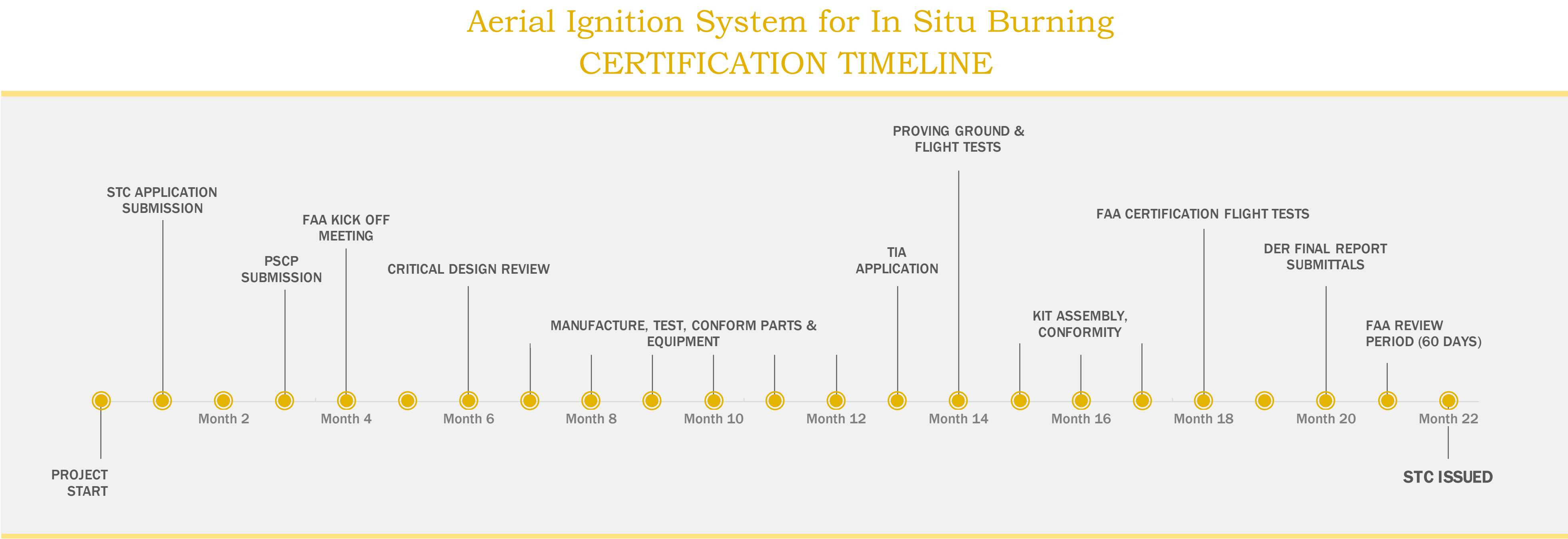
FAA evaluates all final data submittals for compliance with the certification basis. When the FAA determines that the data demonstrates compliance, they will grant final approval of the modification or installation and issue the Applicant an STC. The complete certification basis will be included on FAA Form 8110-2.1 (the continuation sheets of FAA Form 8110-2) and will include a transmittal letter stating that the Applicant has successfully completed all requirements to be granted an STC.

<u>Post Certification Activities</u>

This phase includes:

- • Modification enters service
- • Continued operational safety includes evaluating any failures, malfunctions, or defects.
- • Changes to instructions for continued airworthiness (ICA)
- • Changes and deviations to STC
- • STC data retention (FAA and Applicant)
- • Required documents STC holder must supply at time of aircraft delivery:
    1) Current approved AFMS
    2) Current weight and balance statement
    3) ICA
    4) Compliance status of Ads

Certification Timeline



7. TEST PLAN AND TEST LOCATIONS

7.1 Proof of Concept Testing Overview

Testing of the conceptual design should be done in successive steps, allowing for design concepts to be proven incrementally and financial commitments to testing to be done incrementally based on consecutive successes. Goals of concept testing include: (1) proving the efficiency and effectiveness of the design; (2) proving the safety of the equipment; and (3) providing confidence to move forward with full product development and certification. To that end, it is recommended that testing be conducted in two phases:

7.1.1 Phase 1: Ground Test

High speed ground vehicle testing to prove out designs for fundamental functional elements (pump, ignitors, controls).

7.1.2 Phase 2: Flight Test

Scaled in-flight testing adds interaction of aerodynamic factors not fully available with Ground Testing.

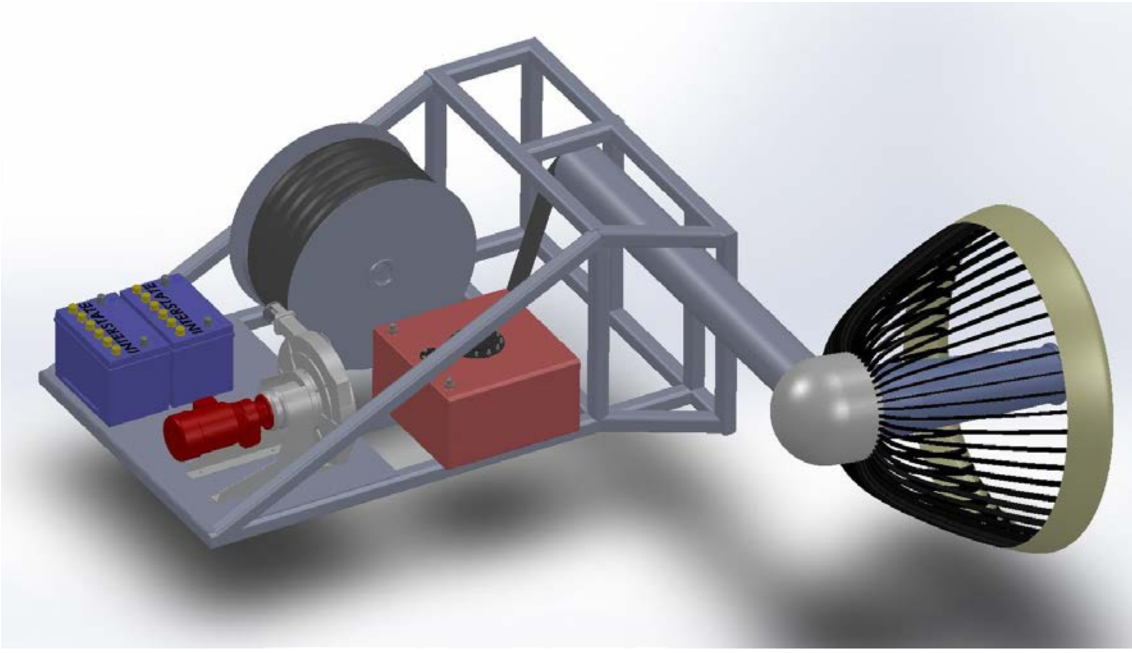
7.2 Test Kit Design

To the extent possible, the test kit will serve both ground and flight test activities. This will save valuable time and reduce overall test expenses.

The test setup will include the following major components:

- Tank –30 gallon aluminum, with fill, discharge and vent fittings
- Tank Heater –28VDC powered
- Pump –Peristaltic positive displacement, 28VDC powered
- Ignition Canister –TBD, stainless steel, fitted with fuel nozzle, ignition devices
- Drogue Chute –Designed to "fly" the canister and hose aft of the test truck/aircraft
- Hose Reel –Designed to manually or electrically deploy and retract the hose and drogue
- Battery Pack –May be needed to provide power to operate the pump and valves (truck or aircraft power available may be insufficient)

Experimental Test Kit Conceptual Design:



7.3 Phase 1: Ground Test

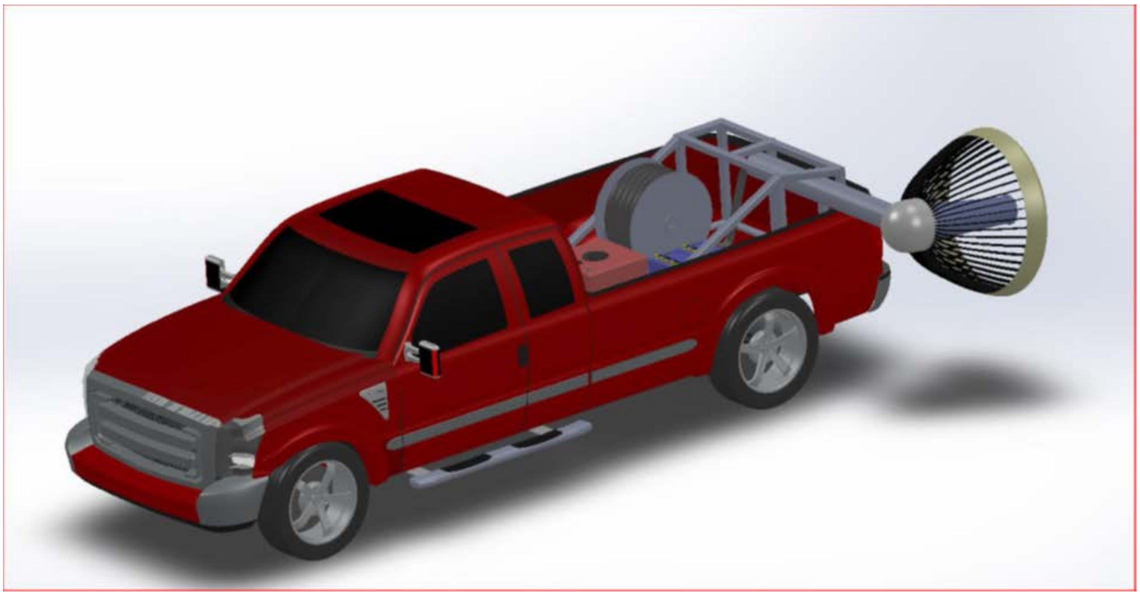
7.3.1 Ground Test Vehicle

A high performance pickup truck would be utilized for the ground test. A high performance pickup truck offers the following benefits for ground testing an ISB system: (1) readily available and affordable; (2) offers acceptable payload capabilities; (3) is capable of maintaining speeds needed for ground tests; and (4) requires minimal modification.

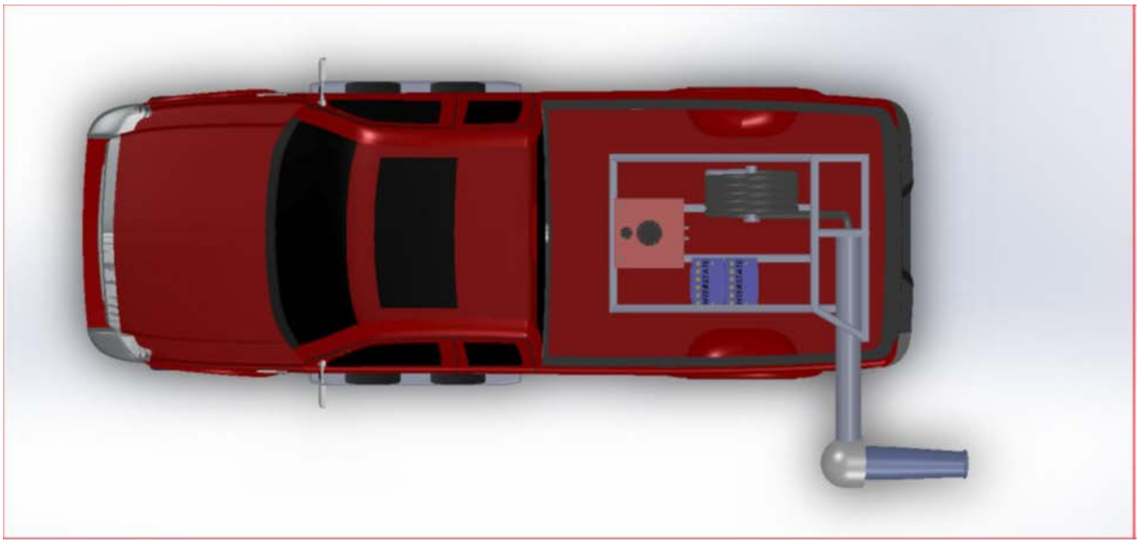
7.3.2 Ground Test Kit Configurations

Three test kit configurations would be utilized, increasing in complexity as the design is proven:

- Primary testing is proposed to validate a "dispensing canister" design. The canister will be hard mounted aft and outboard of the truck footprint;



- Secondary testing adds drogue chute design to the dispensing canister, and is intended to prove integration of the two, especially for aerodynamic interaction; and



- Final test configuration adds a length of hose to the canister/chute assembly, and will demonstrate a fully flying hose/chute/canister. This final assembly will advance to in-flight testing.

7.3.3 Test Execution

To execute the ground test, a minimum of 8500 feet of runway (or roadway) is needed, based on the following test procedures:

- 1500 feet for acceleration to 100 mph;
- ~30 seconds of spray time at 100 MPH, totaling 4250 feet of runway used;
- 1500 feet for deceleration;
- 1250 feet for overrun & safety margin.

The following test procedures will be executed in three distinct runway segments during each test run:

Acceleration Zone:

- Accelerate test vehicle to 100 mph (160 km/h);
- Establish on test route and stabilize at test speed;
- Begin gel fuel dispensing upon reaching dispensing zone.

1500 FT/450 m is allocated for this segment

Gel Fuel Dispensing Zone:

- Several "simulated spill" containment vessels are spaced along the test route;
- At test speed of 100 mph (160 km/h) and established on test route;
- Dispense gelled fuel over test area;
- Dispensing activity will continue for 30 seconds/10 gallons/38 liters;
- Follow vehicle or aircraft will track the test vehicle and video record gel fuel dispensing and ignition effectiveness.

4500 FT/1370 m is allocated for this segment

Decelerate Zone–Stop & Safety Overrun

- Stop dispensing, secure system;
- Retract hose (for hose tests);
- Slow to maneuvering speed, return to staging area.

1500 FT/1370 m is allocated for this segment

1250 FT/380 minimum safety overrun length is available

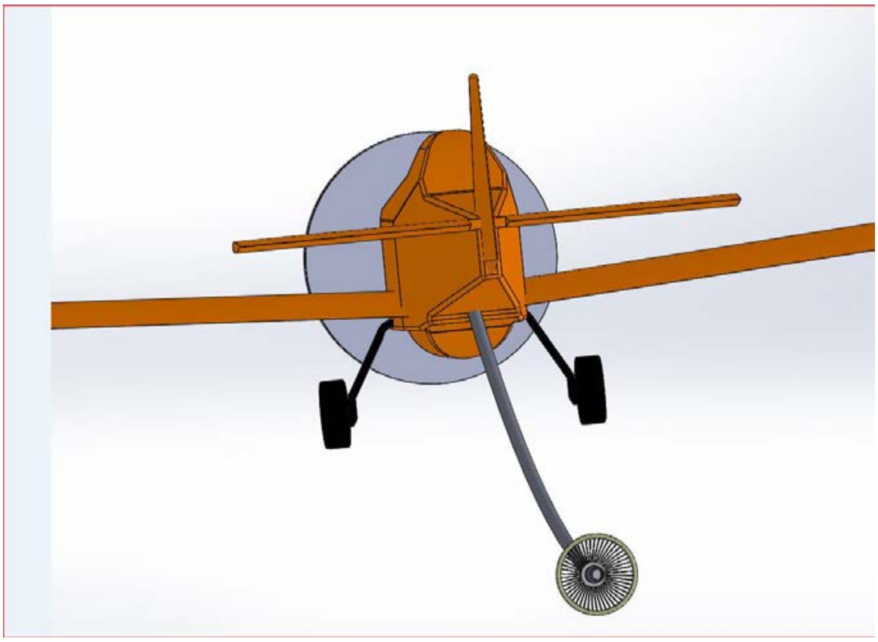
7.4 Phase 2: Flight Test

7.4.1 Flight Test Aircraft

A light twin-engine unpressurized airplane would be utilized for the flight test portion of testing based on the following benefits: (1) readily available and affordable; (2) offers acceptable payload capabilities; (3) is capable of carrying the test kit proposed for these tests; and (4) minimizes unrecoverable investment due to necessary modifications to the airframe. The aircraft would be flown under an FAA experimental certificate, see discussion section 7.5.2.

7.4.2 Flight Test Kit Configuration

Equipment will mount directly to the aircraft cabin floor, and will include the tank, tank heater, peristaltic pump, hose and reel, and piping and control equipment. Primary testing will prove out a hose deployment and retraction design: operable from the pilot or copilot seat; and, demonstrates a high level of safety to aircraft and crew. Secondary testing will demonstrate the fully functioning in situ ignition system. Data and photographs acquired from this ultimate test will present a strong case for moving to a full scale, fully deployable design.



7.4.3 Flight Test Execution

Flight testing will be conduction in two phases:

1. Hose Deployment/Flight Characteristics/Retraction
    - Hose and drogue tests will be conducted without gel fuel loaded;
    - After takeoff, maneuver to the predetermined test area (TBD, clear of populated areas);
    - Established at test altitude (3000 ft above ground level);
    - Establish test speed (variable, expect tests at three operating speeds);
    - System operator will commence deployment of the hose and drogue chute;
    - At regular intervals, an evaluation of flight characteristics will be made and recorded;
    - With the hose and drogue fully deployed, reduce aircraft speed incrementally until reaching minimum operating speed;
    - At minimum speed, observe and record flight characteristics;
    - Accelerate to normal cruise speed, retract hose and drogue to stowed position;
    - A follow aircraft will track and video record tests. Further, drogue vertical position relative to the test aircraft will be estimated and recorded.
2. Dispensing Gelled Fuel
    - After takeoff, maneuver to predetermined test area (TBD but expecting low passes over a closed runway or other appropriate test area);
    - Gel Fuel Dispensing Functional Tests;
    - Initial testing will prove out Hose Deployment (confirmation of earlier tests), Pump and Valve operation, and Ignition System;
    - All dispensing of ignited fuel will be tightly controlled to reliably confine lit fuel impact area;
    - Gel Fuel Dispensing Effectiveness Tests;
    - Successive test runs will present developmental information to select best speeds, altitudes and pump pressure and flow rates;
    - The follow aircraft will track and video record all test activity;
    - Ground fire fighting personnel and equipment will be briefed and present for all tests involving embarked fuel.

7.5 Health, Safety and Environmental Plan (HSE)

7.5.1 Ground Testing

Primary safety risks posed by ground testing include: (1) risk to personnel from high speed driving; (2) flammability risks to personnel and environment; and (3) environmental risks from dispersant and oil. All of these risks can be effectively managed through a comprehensive Health, Safety and Environmental Plan (HSE). A local fire department would also be employed to oversee ground testing.

7.5.2 Company Flight Testing

Proof of concept flight testing will be conducted under an FAA experimental airworthiness certificate, 14 CFR §21.191. A special airworthiness certificate in the experimental category is issued to operate an aircraft that does not have a type certificate or does not conform to its type certificate and is in a condition for safe operation. Special airworthiness certificates may be issued in the experimental category for research and development, specifically to determine if an idea warrants further development.

Experimental airworthiness certificates are governed by the FAA under 14 CFR §21.191, §21.193. FAA maintains safety oversight over operations conducted under an experimental airworthiness certificate and requires an applicant to satisfy the FAA that operations will not pose safety risks to the crew or the public.

7.6 Company Flight Test Budget

Ground Test Cost Estimates	
Truck Acquisition* & Mod	$25,000
Engineering/Design	$25,000
System Kit	$100,000
Ground Test	$5,000

Flight Test Cost Estimates	
Airplane Acquisition* & Mod	$100,000
Aircraft Design/Engineering	$15,000
System Kit Mods & Safety	$20,000
Flight Test	$10,000

*Ground test and flight test estimates are based on the acquisition of the necessary truck and aircraft for ground and flight testing. This recommendation is based on the availability of economical vehicles and aircraft for acquisition that could meet test requirements, as well as the known challenges associated with chartering aircraft for experimental flight testing. An alternative approach to acquisition, would be to rent and charter the necessary vehicles and aircraft for ground and flight testing. Under the charter approach, an aircraft with the minimum necessary airframe modifications should be considered. In addition, separate insurance coverage may be necessary.

Additional Cost Items to Consider:

- Ground Equipment for tests
- Fire Department Support Fees
- Cleanup Crew and Equipment
- Environmental Permits
- FAA Interface and Permits
- Travel Costs

7.7 Ground and Flight Test Location

The primary requirements for a test site location, for both ground and in-flight testing, include:

- Remote location with exclusive availability
- 10,000 ft runway availability
- Concrete runway
- Fire department and support equipment
- Oil cleanup Services
- Cold weather conditions
- Burn permits available

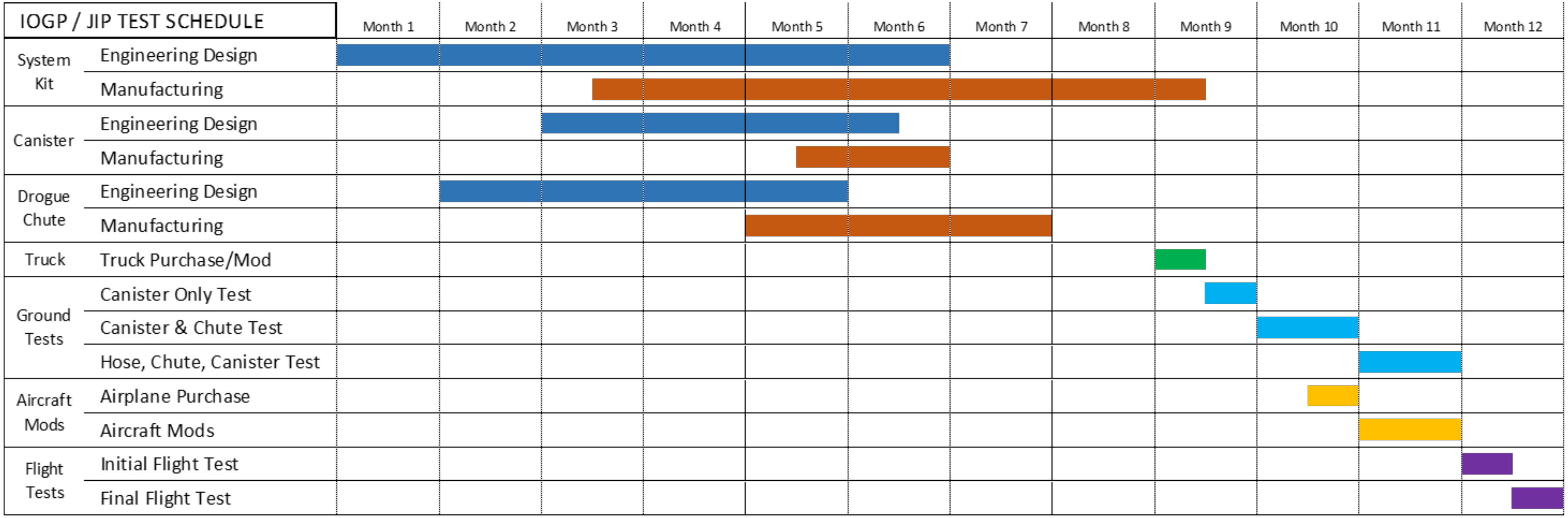
There are multiple locations that meet the primary test location criteria available in the United States. Preference is given to the Moses Lake, Washington location due to extensive experience with flight test programs and necessary support. The Moses Lake airport has two runways meeting the runway criteria, air traffic control, a fire department, an MRO onsite and mild weather almost year-round.

Other potential test sites include:

- Malmstrom Airbase, Montana
- Mojave Field, California
- Bonneville Salt Flats, Utah

Additional information on flight test locations included as **Attachment 3** hereto.

8. ENGINEERING AND TEST SCHEDULE



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ATTACHMENT 1

OTC Paper Number

Development of High Speed Aerial Ignition Techniques For In Situ Burning

T. A. Preli, Shell International E & P; A. A. Allen, Spiltec; D. Glenn, Grasshopper Aviation

This paper was prepared for presentation at the Arctic Technology Conference held in Houston, Texas, USA, 7–9 February 2011.

Abstract

In Situ Burning or ISB is a key oil spill response tactic. The technique is well proven in open water conditions and recently proven effective in Arctic conditions [1]. The safe and effective ignition of spilled oil with gelled fuel, such as that used in a Helitorch, has been well documented and used successfully over the past few decades in many parts of the world. However, the need has been recognized to expand aerial ignition capabilities from a helicopter deployed system, to one that can deliver large payloads of ignition material (typically gelled gasoline) safely and effectively from fixed-wing aircraft.

This paper describes a research and development project involving the field testing of a concept and equipment for the ignition of gelled fuel released from the air at speeds that are two or three times faster than those commonly used when igniting with a helicopter. This "proof of concept" field test is the first step toward the final goal of developing a system that could be operated from a fixed-wing aircraft. Aerial ignition techniques have wide application for a number of spill scenarios. One important scenario involves the ignition of surface oil far from shore. Such ignition capability could significantly enhance the ability to eliminate large quantities of oil in remote locations that are beyond the safe flying distance of helicopter borne systems.

Introduction

Shell's objective in Alaska is to find and develop commercial hydrocarbon resources in the Chukchi and Beaufort Outer Continental Shelf. As with all Shell ventures, the company maintains high operational and social performance standards that will bring, with exploration success, economic expansion and new opportunities to communities across Alaska and the Northwest. Since returning to Alaska in 2005 Shell has embarked on an extensive field data acquisition, R&D and technology maturation effort aimed at supporting exploration and future development. This paper focuses on the development of high speed aerial ignition techniques for in-situ burning, just one of many research projects through which Shell hopes to advance techniques for oil spill response in the Arctic.

In situ burning, or ISB, is a key oil spill response tactic. The technique is well proven in open water conditions and recently proven effective in Arctic conditions [1]. ISB involves the controlled burning of oil that has accidentally been released into the environment. When conducted properly, ISB significantly reduces the amount of oil on the water and minimizes the adverse effects of the oil on the marine environment. Current ignition techniques, typically involving helicopter slung systems such as the Helitorch, do not allow for the safe and efficient ignition of oil when operating at spill locations that are many tens of miles from the nearest staging area. Range/payload constraints for helicopter-deployed ignition systems limit the use of a Helitorch to onshore and near shore operations, with 10 to 20 miles offshore being the safe flying limit from the helicopter's staging area. For the past 25 years, there has been a growing awareness of the need to expand the offshore ignition capabilities to regions up to 50 to 100 miles offshore.

As with the surface application of chemical dispersants, the use of ISB at a remote offshore spill location is best handled with fixed-wing aircraft where sizeable payloads can be delivered many tens of miles away from a staging area while providing ample time on location to carry out an extended search and application mission. The safe and effective ignition of spilled oil with gelled fuel, such as that used in a Helitorch, has been well documented and used successfully over the past few decades in many parts of the world [2,3,4,5]. There is a strong need to expand aerial ignition capabilities to include a fixed-wing delivery system with large payloads of ignition material (e.g., gelled gasoline or aviation gas) safely and effectively to locations far offshore.

A "Proof-of-Concept" test phase was deemed important to determine whether gelled fuel could be ignited and its burn sustained at speeds of typically 80 to 100 knots corresponding to the speed of a small fixed wing aircraft. An aircraft capable of carrying payloads of up to 500 to 800 gallons, could allow the successful application of ignition points 50 to 100 miles offshore over extensive regions while staging from a single shore-based facility. This paper will present the first step taken on an actual field test to prove-up the feasibility of the concept. The paper will present the findings of the "proof of concept" test and also outline the future work required to implement a fixed wing aircraft system for ISB ignition.

Commitment to a Safe Project

It was fully recognized that this R&D Project had many high risk activities. Furthermore, many of these high risk activities were not considered "normal operations." Due to the high risk nature and infrequency of these activities, Shell applied a robust set of Health, Safety, and Environmental (HSE) controls to ensure the protection of people and the environment.

The Aerotorch R&D Project Planning started many months in advance of actually conducting the field test. The specific HSE controls utilized on the Aerotorch R&D Project were as follows:

- Application of Shell's Life Saving Rules
- Detailed Safe Work Plan
- Detailed HSE Plan
- A Rolling Action Item List
- A Dedicated HSE Field Technician
- Daily Job Safety Analysis (JSA) of the Day's Work Tasks

Shell has a detailed set of twelve life saving rules that are mandatory for all of its contractors, subcontractors and Shell staff. Compliance with the Shell Life Saving Rules is not optional and therefore much time was spent training both the sub-contractors and contractors on these rules. A detailed safe work plan was prepared for the Aerotorch field test. All members of the Aerotorch test contributed to the development and review of the safe work plan. Likewise a detailed HSE Plan was developed for the test plan. The HSE plan addressed many of the "non-standard" activities conducted during the field trials.

A one day Hazard Identification (HAZID) workshop was conducted in Kenai, Alaska at the Beacon Facility. The HAZID was conducted approximately three months prior to the field test so that ample time could be taken to mitigate identified risks and hazards. A Monday morning weekly teleconference was also conducted as an HSE control measure. Participation in the weekly teleconference was mandatory for all of the ten team members. The weekly meeting typically lasted one hour and served as an excellent way to communicate and team build amongst the many diverse team members. A detailed rolling action item list was kept during the weekly teleconference process. Over eighty action items were generated, assigned to various team members and completed prior to the field work starting. The rigorous HSE controls applied by Shell on this project were seen as a critical success factor in allowing the field test to be conducted without any incidents. A deep commitment by all Aerotorch R&D Project team members was also a contributing factor to the flawless field test.

A Phased Approach to Aerotorch R&D Project

Shell took a phased approach to the Aerotorch R&D Project. The phases for the project were broken down as follows:

Phase 1A - Initial	Proof of Concept, Kenai, Alaska Complete October, 2010
Phase 1B – Planned	Cold Weather & Additional Chamber Tests Last Week of February, 2011 Kenai, Alaska
Phase 2 – Desktop	March 2011 till December 2012

Phase 3 – Integration into Aviation - 2013

Phase 4 – Field Test with Aviation - 2014

Commitment to Local Content

Shell had a strong commitment to local content for the Aerotorch R&D Project. Many of the contractors and subcontractors were Alaska based. Utilizing local contractors and sub-contractors accomplished a variety of goals. First, utilization of a local facility and contractors helped create a local spend in the State of Alaska and build local capacity for the future. Second, the local contractors and subcontractors provided knowledge regarding Arctic conditions. Shell intends to continue with its commitment of local content for future phases of the Aerotorch R&D Project.

Test Set-Up and Planning

Shell, in association with Spiltec and its subcontractors, conducted a series of tests at the Beacon Training Center in Kenai, Alaska. The purpose of the testing was to confirm that thickened fuel (gasoline, diesel, aviation gas or combinations of these) could be ignited in wind velocities ranging from 80 to well over 100 mph, simulating the ignition from a fixed wing aircraft onto spilled oil. All work conducted for this project was ground-based and did not include any aircraft. A Helitorch (designed for helicopter use and manufactured by Simplex Manufacturing) was used to store and pump gelled fuel. All mixing of the gelled fuel was completed in a separate Terra-Torch, provided by the Alaska Fire Service.

This test included the following companies:

Shell Alaska Venture Team – Houston, Texas
Shell HSE/EER – Houston, Texas and Anchorage, Alaska
Spiltec – Woodinville, Washington
Grasshopper Aviation – Wasilla, Alaska
Beacon Training Center – Kenai, Alaska
Type One Products – Bend, Oregon
Simplex Manufacturing – Portland, Oregon
Old Harbor Native Company – Kodiak Island, Alaska
Alaska Fire Service – Fort Wainwright, Alaska
DVD Technology – Hatchers Pass, Alaska

Test Location Site:

The Beacon Training Center located at 450 Marathon Road, Kenai, Alaska provides fire training for fire fighters from all over the state of Alaska, and was an ideal site for the completion of all burn tests conducted during this project (See Figure 1).

Figure 1 - Beacon Training Center

Test Scenario:

Utilizing a specially designed and constructed trailer-mounted wind machine (see Figure 2); several different nozzle/shroud assemblies were tested, one at a time, directly into the wind stream to determine the best assembly for potential use with a fixed wing aircraft.

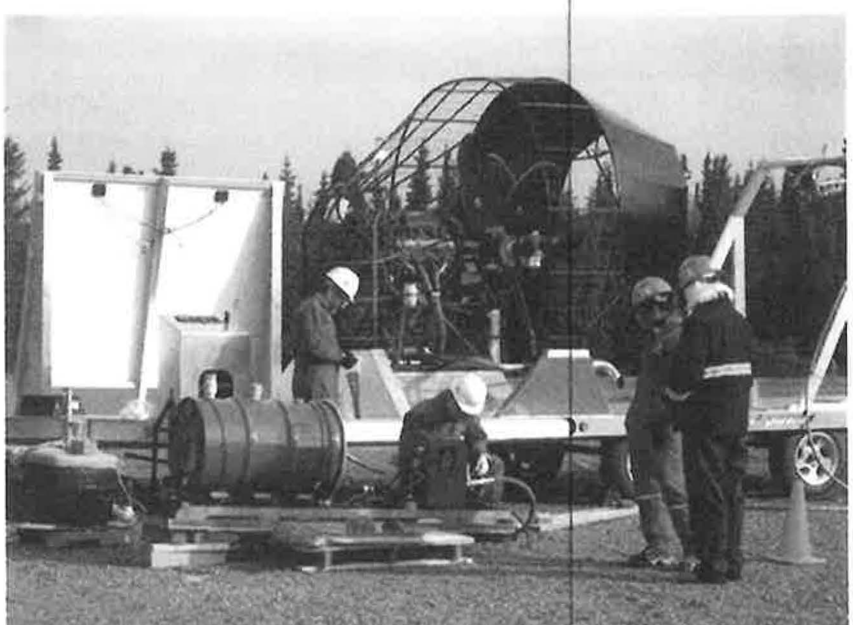

Figure 2 - Trailer Mounted Wind Machine

The wind machine incorporates a large V8 engine that drives two counter rotating propellers. By varying the speed of the engine, wind speeds can be adjusted from approximately 20 to 120 mph. The screen enclosed propeller blades are approximately ten feet from the rear of the trailer deck platform. Mounted on the rear of the trailer deck is a certified aircraft airspeed indicator used to record wind velocity (see Figure 3). The operation of the wind machine was controlled by a single operator located near the front of the flatbed trailer. The airspeed indicator gauge was located at the operator's console for ease of use. The airspeed indicator gauge readout was in mph, thus all test results are presented in mph as opposed to knots. The wind machine trailer was attached to a large SUV to add more stability during operations.

The pumping and ignition system utilized on a standard Helitorch manufactured by Simplex Manufacturing provided the required gelled fuel pumping and ignition system. The gelled fuel was mixed in a re-circulating gel mixer provided by Alaska

Fire Service. By regulating the flow, the test team was able to compensate for differences in gel viscosity and other environmental factors affecting ignition. For the test, the "wand" or "gun" that fires the gel on the Terra-Torch was used to pump gelled fuel into the Helitorch storage tank. The piping system from the gelled fuel fifty-five gallon reservoir to the torch shroud head was modified by extending the piping system fifteen feet. A propane line and electrical lines to ignite the gel were also extended about fifteen feet.

The entire system to support the nozzle/shroud assembly and the support cables was attached to an A-Frame welded to the wind-machine's trailer bed. The A-Frame was placed in position approximately 25' downstream from the blades of the wind machine. The aircraft airspeed indicator was mounted on the A-Frame to record wind velocity at the nozzle/shroud assembly. See the Figure 3 below for a more detailed version of the test set-up.

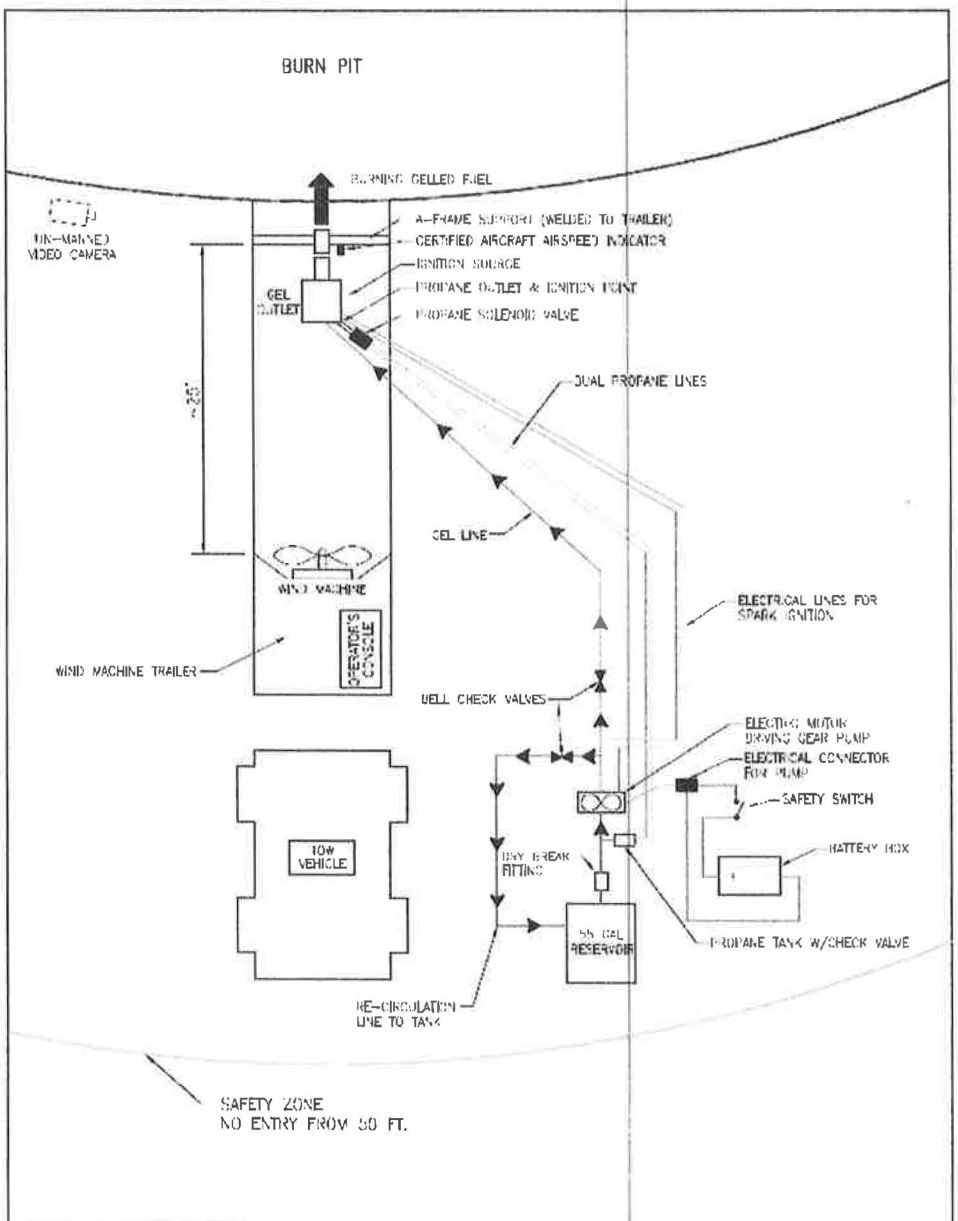

Figure 3 – Test Set-Up P&ID

More than 60 individual tests with wind speeds ranging from 40 mph to as high as 120 mph (in some cases) with varying gelled-fuel flow rates and different nozzle/shroud assemblies were used. The test data were recorded by personnel, and shown on a master "Data White Board" on site. The data board and all activities were recorded with still cameras and four video cameras. All recording equipment was operated by a professional videographer (DVD Technology).

Test Procedure:

The wind machine was positioned within the fire training area, while the Helitorch was positioned to the rear of the wind machine trailer (See Figure 4).

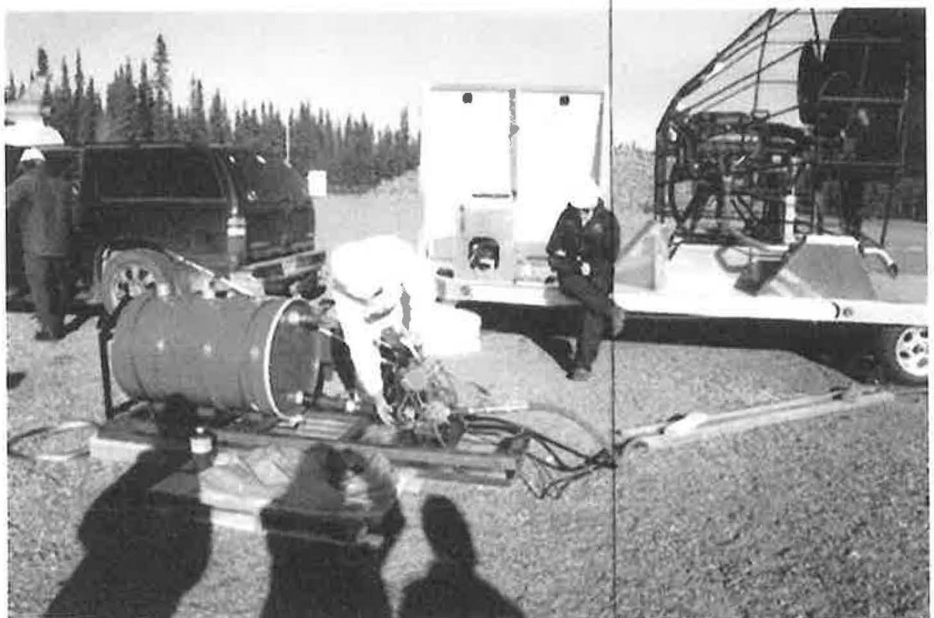

Figure 4 – Modified Helitorch – Simplex Model 5400

The Helitorch piping system was secured to the A-Frame via tie-wraps at a level that provided the best exposure to the wind stream. A dry run of the wind machine at wind speeds from 40 to 120 mph was initially conducted prior to introducing the gel for ignition.

The battery pack required for ignition of the propane pilot light was located approximately five feet to the side of the Helitorch and attached via extended wiring. The battery pack was wired to the circuit breaker junction box for safety. The Helitorch operator's location is shown in Figure 3 on the wind machine behind the Helitorch. Once all of the equipment was positioned and secured, testing commenced. Hand signals were employed prior to and during testing to communicate with the operators.

Typical operations per test were as follows:

- Video cameras were started to record activity prior to testing. The best location(s) to position the video cameras was determined before testing to ensure accurate recording of the testing. Cameras were also positioned at various locations to record the various components during operation.
- The certified aircraft airspeed indicator was verified and working properly.
- Wind machine initial air velocity set at appropriate "Start Speed" (this varied for different tests – some starting at 80 mph, others at 40 mph)
- Pumping rate of gel set at approximately 13 gpm for most tests (some at lower pump rate)
- Flame Test (assessment of propane flow and ignition, without wind and gel)
- Gel ignited at torch head.
- Test duration was typically 10 seconds.
- Once a test was completed the wind speed was increased by 10 mph and another test was conducted. This was repeated until there was a clear indication of the gel not being ignited. No test was performed at wind velocities greater than 120 mph.

Flow rates were controlled by adjusting the ball valve located upstream from the pump. Once an estimated desired position was selected, the flow was calibrated by activating the pump and catching the discharge of gel in a measuring container. The discharged gel was then returned to the gel tank for reuse. Prior to activating the pump for calibration testing it was required that the propane supply valve be closed and the ignition electrical system be deactivated. Both of these systems were tagged out with appropriate marking tags.

Field Trial Observations

Numerous tests were conducted over a four-day period with different types and orientations of test shrouds, various "burn chamber" lengths, and a variety of airflow size and orientation openings. Throughout the test period, the weather was clear, without rain or snow, calm to very light wind conditions, and air temperatures ranging from slightly below freezing in the morning to approximately 45° F by mid-afternoon.

The first set of tests incorporated a cylindrical shroud with twin propane exit ports and igniter tips within the shroud. A single gelled fuel nozzle was positioned at the center of the shroud, and the entire assembly was tilted downward at an angle of 45° (see Figure 5).

Figure 5 – Test Cylinder at 45° Angle

A variety of air inlets were tested and varied in size on the back and side of the nozzle assembly. During the initial tests, the gelled mix consisted of a 50/50 aviation gas and diesel blend; however, findings soon revealed the need to work with 100 % aviation gas. Throughout the entire test program all gelling of fuel was accomplished with Flash 21 gelling agent provided by Type One Incident Support Inc.

While working with a 100% aviation gas gel, tests continued with a variety of air-intake and nozzle orientations. The original cylindrical shroud was tested at both 45° (angle to the wind), and in a horizontal position. Tests were conducted at wind speeds of typically 40 mph to well over 100 mph, and with full air inlet openings (i.e., with upwind plate removed from the cylinder), with partial closures of the air inlets, and with full closure (i.e., no air fed directly to the interior of the nozzle assembly). The results revealed that a horizontal position of the nozzle assembly with partial air openings on the back plate (i.e., plate facing the wind generator) provided the best results. Improvements were noted with ignition of the gelled fuel occurring as it exited the cylindrical chamber, and with sustained ignition occurring downwind at wind speeds as high as 90 mph. Burning globules were landing on the ground, but because the wind generator was positioned with its center only 6 to 7 feet above ground level, such globules could be blown out within seconds. Experience over the years has shown that burning globules of gelled fuel (typically fist-sized, or smaller), can be blown out with winds of 20 to 25 mph.

As the week of testing progressed, modifications to the nozzle/shroud assembly included variations in the gelled fuel pump rate and changes to the length of the cylindrical chamber. It was recognized that the lengthening of the cylinder gave better results, apparently because of the longer exposure time of the gelled fuel to flame within the chamber. Figure 6 shows the extension of the nozzle/shroud assembly with the addition of a 25-inch-long piece of "stove pipe".

Figure 6 – Cylinder in the Horizontal with "Stove Pipe" Extension

The horizontal position of the cylinder also gave better results, as any angular position appeared to shear the burning gelled fuel (upon exiting the cylinder), causing it to break into smaller globules.

The tests with lower pump rates of the gelled fuel (i.e., from the usual 13 to 15 gpm down to 6 to 7 gpm) revealed that the higher flow rates from the nozzle were essential to discharge the gelled fuel with a desirable exit speed through and out the end of the cylindrical shroud. Proper gelled fuel exit speed and flow pattern were found to be influenced as well by the use (or omission) of the spring-loaded plunger within the gelled fuel nozzle, and by the positioning of the electrical ignition tips immediately downstream of the nozzle. By removing the spring-loaded plunger (used simply to give instant closure of the nozzle when the pump was stopped), and by positioning the igniter tips away from the initial path of the gelled fuel, a better size and ignition of the gelled fuel globules was achieved.

Having maximized the performance of the cylindrical nozzle/shroud assembly available, tests were then conducted with more conventional flat-plate shrouds similar to those used on the Simplex Helitorch. Using two different flat-plate designs, oriented parallel to the wind (to avoid high-wind shearing of the gelled fuel), it was quickly recognized that flame-exposure time was critical when attempting to ignite gelled fuel at wind speeds commonly associated with a fixed-wing aircraft. It was felt that further testing of such flat-plate nozzle/shroud configurations would yield little, if any, favorable results.

Toward the end of the field trials a few scaled "static" tests were conducted with a variety aviation-gas/diesel gelled fuel mixes by placing the same volume of mix on water and noting their viscosity, spread and burn time. Each test involved approximately 1 cup of gelled fuel, ranging from 100% aviation gas/no diesel to 50% aviation gas/50% diesel. With air and water temperatures just slightly above freezing, the highest aviation-gas mixtures (100% and 90%) gave the smallest diameter globules (approximately 4 inches after spreading on the water), yielding burn times of nearly 8 minutes. The lowest aviation-gas mixture (50%) with 50% diesel resulted in an 11-inch diameter patty on water and a burn time of only approximately 2 minutes. These tests established baseline data and do not necessarily represent operational burn times. Further static testing with representative gelled fuel volumes will be undertaken in follow-up testing.

Summary of Test Conclusions

The original objective of the "proof of concept" test was to explore the possibility of igniting gelled fuel released from a nozzle/shroud configuration at air speeds of 80 to 100 mph or higher. The objective of the first phase of this "proof of concept" effort was achieved. It was determined that for air temperatures near and slightly above freezing (approximately 25° to 45° F), a nozzle/shroud configuration could be developed that would allow for the effective ignition of gelled fuel at speeds well in excess of 80 mph, the minimum air speed at which the team anticipated ignitions from a fixed-wing aircraft. First-phase test results suggest that a 100% aviation-gas, gelled fuel mix (currently using Flash 21 gelling agent), released from an open-orifice nozzle, contained within a cylindrical shroud , could be used successfully to ignite the gelled fuel with air speeds (at the nozzle/shroud assembly) of between 80 mph and 100 mph. The best results to date suggest that the nozzle/shroud assembly should be positioned at or slightly below a horizontal position, facing directly aft (i.e., downwind), and have an extended cylindrical shroud of at least 20 to 30 inches, completely encasing the gelled fuel nozzle, propane release ports, and the electrical ignition points.

The ignition assembly tested during this set of field trials appears to work best with a gelled-fuel flow rate of 13 to 15 gpm, with an open orifice (i.e., spring-loaded plunger removed), and air-inlet openings that can be adjusted – the best tentative openings on the upwind plate of the cylindrical wall, consisting of one (or possibly multiple) air inlets of typically 25% or less of the plate area.

Since this first phase was aimed at only the initial ignition of gelled fuel at high wind speeds, the field trials could be conducted with the wind generator at ground level. The results (involving successful ignition "in the air") are difficult to assess as they relate to the successful "sustained" combustion of the ignited gelled-fuel globules and their ability to remain lit upon impact at ground/water level. The best gel-mix and equipment configurations tested often resulted in what appeared to be extensive, sustained ignition points on the ground (often 60 to 80 feet or more downwind of their release point). However, it is difficult to make any conclusion at this point regarding sustained combustion through free-fall and ground-level impact. It is believed, based on many observations of burning gelled fuel from a Helitorch at approximately 40 to 50 mph, that the ignited globules from a fixed-wing aircraft will slow down quickly (i.e., their horizontal velocity) and reach a terminal vertical velocity that is similar to globules produced from a Helitorch.

Future Field Tests

As a part of this initial phase of field trials, it is felt that additional testing is needed with at least two or three enhanced versions of the cylindrical nozzle/shroud assembly. Using lessons learned during the first trials, modifications are being made to type and configuration of the gelled-fuel nozzle, the propane exit ports and the electrical ignition points. Construction is underway to provide an extended cylinder with increased heat-exchange capabilities over a greater portion of the cylinder. Higher temperatures and exposure times between the gelled fuel and the heat source are expected. The testing of these enhanced nozzle/shroud configurations are envisioned as a continuation of this project (Phase 1B). Phase 1B will likely be conducted the last week of February, 2011, allowing for additional test benefits including colder conditions. This is important as some of the potential oil spill scenarios for which this system could be used include the controlled burning of oil during the coldest mid-winter conditions in the Arctic.

Once Phase 1B is completed, a "Desk Top Study" will be conducted (Phase 2) to study a comprehensive "Aircraft/Aerotorch Analysis" of all safety issues, tactical considerations, FAA and other regulatory constraints, candidate aircraft, Aerotorch design & construction possibilities, and procedures/location for further field testing of a full-scale Aerotorch system.

Upon successful completion of Phase 2, Phase 3 will then be conducted involving the completion of a number of "dry" runs (that is, flight testing of aircraft and Aerotorch on land without ignition of gelled fuel) and a series of full-scale simulation runs in which gelled fuel could be released onto an approved land site and/or pans/ponds of water with oil. Phase 4 would include actual releases of burning gelled fuel at a remote location offshore.

Future Efforts

Shell is committed to seeking industry and regulatory support for further development and certification of this concept. Shell will also seek potential funding from the International Petroleum Industry Environmental Conservation Association (IPIECA), the American Petroleum Industry, individual oil companies and Government Agencies. While moving forward with the Aerotorch R&D Project, Shell will make every effort to involve and seek support from internal and external aviation specialists that can provide guidance for the ultimate development of a safe and effective means of igniting spilled oil at sea under a broad range of environmental conditions.

Support for the Aerotorch may well come from other potential users of this technology. For example, interest has been shown by those involved with the control of forest fires. The safe, rapid and effective delivery of multiple ignition points could help during the creation of fire breaks to control the spread of fires on land and to assist with the deliberate burning of slash piles or with controlled agricultural burns.

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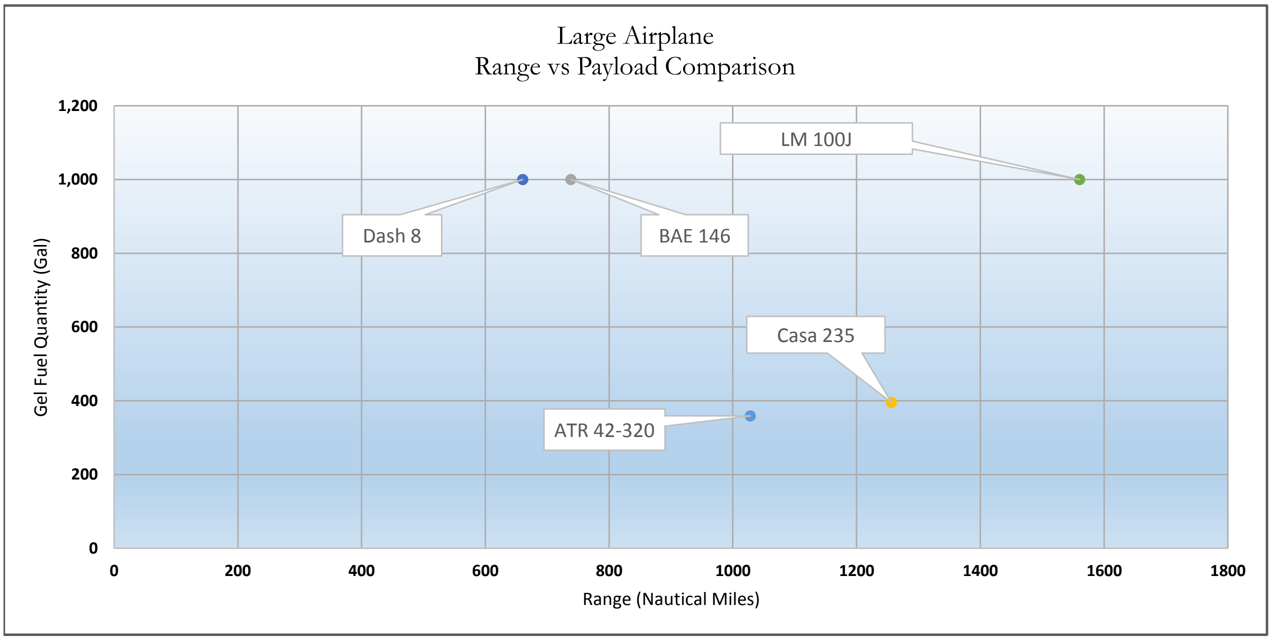
ATTACHMENT 2



ATR 42-320

	Data	Notes	
Aircraft Max Gross or Max TO:	36,870	From TCDS	
Aircraft Max Fuel Capacity	9,921	From TCDS	
Empty Weight	22,200	From Mfr. Data	
Crew (3@220 LBS)	660		
WP Gel Pump/Igniter System (Est.)	500		
Payload Available for Gel Fuel	3,589	= GW minus fuel, crew, EW & pump	
Calculated Gel Fuel (gallons)	359	=Payload Wt. divided by 10	
Gel Fuel Quantity (Lesser of calc amount or 1000 gal)	**359**	MIN Function picks lesser value	**Chart Value**
Loiter Time (Hours)	0.36	@1000gph, Used in Range Calc.	
Fuel Burn (LB/Hr)	1,200	From Mfr. Data, or calculated	
Total Duration at Full Fuel (Hours)	8.27	=Fuel Capacity/Fuel Burn Rate	
Cruise Duration after subtracting Loiter	7.91	=Total Duration minus Loiter Time	
Cruise Speed (Kts)	260	From Mfr. Data	
Cruise Range	2,056	=Cruise Duration x Speed	
Range /2 (Out & Back)	**1028**	=Cruise Range / 2	**Chart Value**

BAE 146

	Data	Notes	
Aircraft Max Gross or Max TO:	93,500	From TCDS	
Aircraft Max Fuel Capacity	20,640	From TCDS	
Empty Weight	52,200	From Mfr. Data	
Crew (3@220 LBS)	660		
WP Gel Pump/Igniter System (Est.)	500		
Payload Available for Gel Fuel	19,500	= GW minus fuel, crew, EW & pump	
Calculated Gel Fuel (gallons)	1,950	=Payload Wt. divided by 10	
Gel Fuel Quantity (Lesser of calc amount or 1000 gal)	**1,000**	MIN Function picks lesser value	**Chart Value**
Loiter Time (Hours)	1.00	@1000gph, Used in Range Calc.	
Fuel Burn (LB/Hr)	4,400	From Mfr. Data, or calculated	
Total Duration at Full Fuel (Hours)	4.69	=Fuel Capacity/Fuel Burn Rate	
Cruise Duration after subtracting Loiter	3.69	=Total Duration minus Loiter Time	
Cruise Speed (Kts)	400	From Mfr. Data	
Cruise Range	1,476	=Cruise Duration x Speed	
Range /2 (Out & Back)	**738**	=Cruise Range / 2	**Chart Value**

Casa 235

	Data	Notes
Aircraft Max Gross or Max TO:	34,940	From TCDS

Aircraft Max Fuel Capacity	9,426	From TCDS	
Empty Weight	20,400	From Mfr. Data	
Crew (3@220 LBS)	660		
WP Gel Pump/Igniter System (Est.)	500		
Payload Available for Gel Fuel	3,954	= GW minus fuel, crew, EW & pump	
Calculated Gel Fuel (gallons)	395	=Payload Wt. divided by 10	
Gel Fuel Quantity (Lesser of calc amount or 1000 gal)	**395**	MIN Function picks lesser value	**Chart Value**
Loiter Time (Hours)	0.40	@1000gph, Used in Range Calc.	
Fuel Burn (LB/Hr)	885	From Mfr. Data, or calculated	
Total Duration at Full Fuel (Hours)	10.65	=Fuel Capacity/Fuel Burn Rate	
Cruise Duration after subtracting Loiter	10.26	=Total Duration minus Loiter Time	
Cruise Speed (Kts)	245	From Mfr. Data	
Cruise Range	2,513	=Cruise Duration x Speed	
Range /2 (Out & Back)	**1256**	=Cruise Range / 2	**Chart Value**

Dash 8

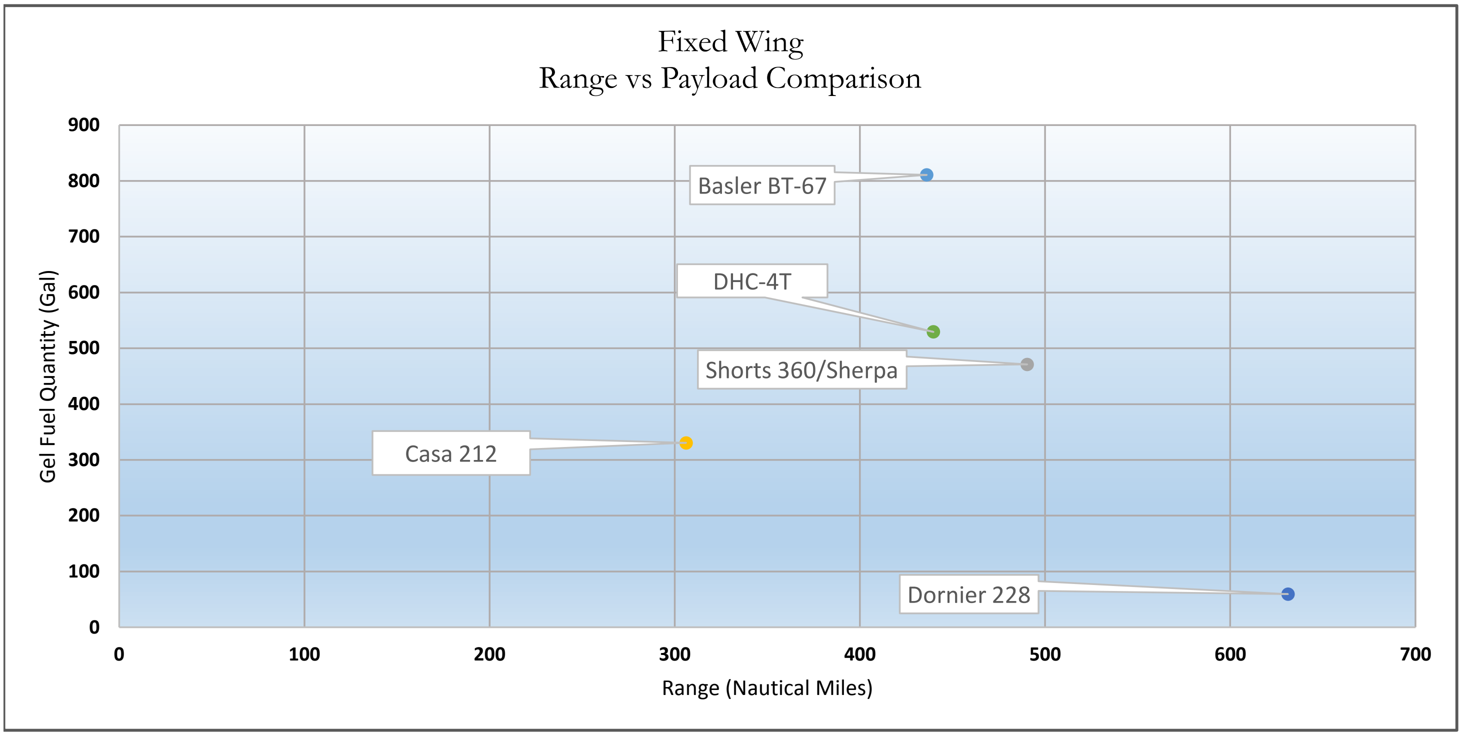
	Data	Notes	
Aircraft Max Gross or Max TO:	65,400	From TCDS	
Aircraft Max Fuel Capacity	11,884	From TCDS	
Empty Weight	36,550	From Mfr. Data	
Crew (3@220 LBS)	660		
WP Gel Pump/Igniter System (Est.)	500		
Payload Available for Gel Fuel	15,806	= GW minus fuel, crew, EW & pump	
Calculated Gel Fuel (gallons)	1,581	=Payload Wt. divided by 10	
Gel Fuel Quantity (Lesser of calc amount or 1000 gal)	**1,000**	MIN Function picks lesser value	**Chart Value**
Loiter Time (Hours)	1.00	@1000gph, Used in Range Calc.	
Fuel Burn (LB/Hr)	2,200	From Mfr. Data, or calculated	
Total Duration at Full Fuel (Hours)	5.40	=Fuel Capacity/Fuel Burn Rate	
Cruise Duration after subtracting Loiter	4.40	=Total Duration minus Loiter Time	
Cruise Speed (Kts)	300	From Mfr. Data	
Cruise Range	1,321	=Cruise Duration x Speed	
Range /2 (Out & Back)	**660**	=Cruise Range / 2	**Chart Value**

LM 100J

	Data	Notes	
Aircraft Max Gross or Max TO:	164,800	From TCDS	
Aircraft Max Fuel Capacity	47,888	From TCDs	
Empty Weight	80,400	From Mfr. Data	
Crew (3@220 LBS)	660		
WP Gel Pump/Igniter System (Est.)	500		
Payload Available for Gel Fuel	35,352	= GW minus fuel, crew, EW & pump	
Calculated Gel Fuel (gallons)	3,535	=Payload Wt. divided by 10	
Gel Fuel Quantity (Lesser of calc amount or 1000 gal)	**1,000**	MIN Function picks lesser value	**Chart Value**
Loiter Time (Hours)	1.00	@1000gph, Used in Range Calc.	
Fuel Burn (LB/Hr)	4,200	From Mfr. Data, or calculated	
Total Duration at Full Fuel (Hours)	11.40	=Fuel Capacity/Fuel Burn Rate	
Cruise Duration after subtracting Loiter	10.40	=Total Duration minus Loiter Time	
Cruise Speed (Kts)	300	From Mfr. Data	
Cruise Range	3,121	=Cruise Duration x Speed	
Range /2 (Out & Back)	**1560**	=Cruise Range / 2	**Chart Value**

ATR 42-320	Range (1 way)	0	1028	1028	1028
	Gel Fuel Qty	359	359	0	0
BAE 146	Range (1 way)	0	738	738	738
	Gel Fuel Qty	1,000	1,000	0	0
Casa 235	Range (1 way)	0	1256	1256	1256
	Gel Fuel Qty	395	395	0	0
Dash 8	Range (1 way)	0	660	660	660

Dash 8	Gel Fuel Qty	1,000	1,000	0	0
LM 100J	Range (1 way)	0	1560	1560	1560
	Gel Fuel Qty	1,000	1,000	0	0



Basler BT-67	Data	Notes	
Maximum Gross or Max TO Weight:	30,000	From TCDS	
Aircraft Max Fuel Capacity	5,172	From Mfr. Data	
Empty Weight	15,560	From Mfr. Data	
Crew (3@220 LBS)	660		
WP Gel Pump/Igniter System (Est.)	500		
Payload Available for Gel Fuel	8,108	= GW minus fuel, crew, EW & pump	
Calculated Gel Fuel (gallons)	811	=Payload Wt. divided by 10	
Gel Fuel Quantity (Lesser of calc amount or 1000 gal)	**811**	MIN Function picks lesser value	**Chart Value**
Loiter Time (Hours)	0.81	@1000gph, Used in Range Calc.	
Fuel Burn (LB/Hr)	1,000	From Mfr. Data	
Total Duration at Full Fuel (Hours)	5.17	=Fuel Capacity/Fuel Burn Rate	
Cruise Duration after subtracting Loiter	4.36	=Total Duration minus Loiter Time	
Cruise Speed (Kts)	200	From Mfr. Data	
Cruise Range	872	=Cruise Duration x Speed	
Range /2 (Out & Back)	**436**	=Cruise Range / 2	**Chart Value**

Shorts 360/Sherpa	Data	Notes	
Maximum Gross or Max TO Weight:	25,600	From TCDS	
Aircraft Max Fuel Capacity	4,368	From TCDS	
Empty Weight	15,360	From Mfr. Data	
Crew (3@220 LBS)	660		
WP Gel Pump/Igniter System (Est.)	500		
Payload Available for Gel Fuel	4,712	= GW minus fuel, crew, EW & pump	
Calculated Gel Fuel (gallons)	471	=Payload Wt. divided by 10	
Gel Fuel Quantity (Lesser of calc amount or 1000 gal)	**471**	MIN Function picks lesser value	**Chart Value**
Loiter Time (Hours)	0.47	@1000gph, Used in Range Calc.	
Fuel Burn (LB/Hr)	700	From Mfr. Data, or calculated	

Total Duration at Full Fuel (Hours)	6.24	=Fuel Capacity/Fuel Burn Rate	
Cruise Duration after subtracting Loiter	5.77	=Total Duration minus Loiter Time	
Cruise Speed (Kts)	170	From Mfr. Data	
Cruise Range	981	=Cruise Duration x Speed	
Range /2 (Out & Back)	**490**	=Cruise Range / 2	**Chart Value**

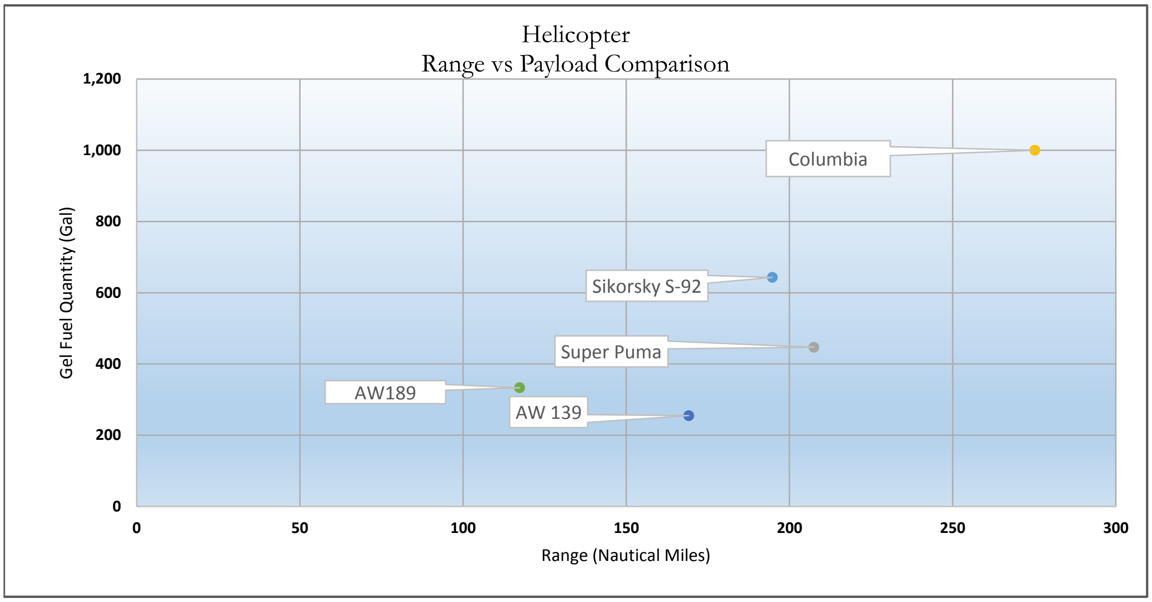
Casa 212	**Data**	**Notes**	
Maximum Gross or Max TO Weight:	16,796	From TCDS	
Aircraft Max Fuel Capacity	3,530	From TCDS	
Empty Weight	8,800	From Mfr. Data	
Crew (3@220 LBS)	660		
WP Gel Pump/Igniter System (Est.)	500		
Payload Available for Gel Fuel	3,306	= GW minus fuel, crew, EW & pump	
Calculated Gel Fuel (gallons)	331	=Payload Wt. divided by 10	
Gel Fuel Quantity (Lesser of calc amount or 1000 gal)	**331**	MIN Function picks lesser value	**Chart Value**
Loiter Time (Hours)	0.33	@1000gph, Used in Range Calc.	
Fuel Burn (LB/Hr)	800	From Mfr. Data	
Total Duration at Full Fuel (Hours)	4.41	=Fuel Capacity/Fuel Burn Rate	
Cruise Duration after subtracting Loiter	4.08	=Total Duration minus Loiter Time	
Cruise Speed (Kts)	150	From Mfr. Data	
Cruise Range	612	=Cruise Duration x Speed	
Range /2 (Out & Back)	**306**	=Cruise Range / 2	**Chart Value**

Dornier 228	**Data**	**Notes**	
Maximum Gross or Max TO Weight:	14,110	From TCDS	
Aircraft Max Fuel Capacity	4,156	From TCDS	
Empty Weight	8,200	From Mfr. Data	
Crew (3@220 LBS)	660		
WP Gel Pump/Igniter System (Est.)	500		
Payload Available for Gel Fuel	594	=GW minus fuel, crew, EW & pump	
Calculated Gel Fuel (gallons)	59	=Payload Wt. divided by 10	
Gel Fuel Quantity (Lesser of calc amount or 1000 gal)	**59**	MIN Function picks lesser value	**Chart Value**
Loiter Time (Hours)	0.06	@1000gph, Used in Range Calc.	
Fuel Burn (LB/Hr)	620	From Mfr. Data	
Total Duration at Full Fuel (Hours)	6.70	=Fuel Capacity/Fuel Burn Rate	
Cruise Duration after subtracting Loiter	6.64	=Total Duration minus Loiter Time	
Cruise Speed (Kts)	190	From Mfr. Data	
Cruise Range	1,262	=Cruise Duration x Speed	
Range /2 (Out & Back)	**631**	=Cruise Range / 2	**Chart Value**

DHC-4T Turbo Caribou	**Data**	**Notes**
Maximum Gross or Max TO Weight:	28,500	From Mfr. Data
Aircraft Maximum Fuel Capacity	5,547	FromTCDS
Empty Weight	16,500	From Mfr. Data
Crew (3@220 LBS)	660	
WP Gel Pump/Igniter System (Est.)	500	
Payload Available for Gel Fuel	5,293	= GW minus fuel, crew, EW & pump
Calculated Gel Fuel (gallons)	529	=Payload Wt. divided by 10

Gel Fuel Quantity (Lesser of calc amount or 1000 gal)	**529**	MIN Function picks lesser value	**Chart Value**
Loiter Time (Hours)	0.53	@1000gph, Used in Range Calc.	
Fuel Burn (LB/Hr)	910	From Mfr. Data	
Total Duration at Full Fuel (Hours)	6.10	=Fuel Capacity/Fuel Burn Rate	
Cruise Duration after subtracting Loiter	5.57	=Total Duration minus Loiter Time	
Cruise Speed (Kts)	158	From Mfr. Data	
Cruise Range	879	=Cruise Duration x Speed	
Range /2 (Out & Back)	**440**	=Cruise Range / 2	**Chart Value**

Basler BT-67	Range (1 way)	0	436	436	436
	Gel Fuel Qty	811	811	0	0
Shorts 360/Sherpa	Range (1 way)	0	490	490	490
	Gel Fuel Qty	471	471	0	0
Casa 212	Range (1 way)	0	306	306	306
	Gel Fuel Qty	331	331	0	0
Dornier 228	Range (1 way)	0	631	631	631
	Gel Fuel Qty	59	59	0	0
DHC-4T Turbo	Range (1 way)	0	440	440	440
Caribou	Gel Fuel Qty	529	529	0	0



Sikorsky S-92	Data	Notes	
Maximum Gross or Max TO Weight:	26,500	From TCDS	
Aircraft Max Fuel Capacity	3,850	From Mfr. Data	
Empty Weight	15,060	From Mfr. Data	
Crew (3@220 LBS)	660		
WP Gel Pump/Igniter System (Est.)	500		
Payload Available for Gel Fuel	6,430	= GW minus fuel, crew, EW & pump	
Calculated Gel Fuel (gallons)	643	=Payload Wt. divided by 10	
Gel Fuel Quantity (Lesser of calc amount or 1000 gal)	**643**	MIN Function picks lesser value	**Chart Value**
Loiter Time (Hours)	0.64	@1000gph, Used in Range Calc.	
Fuel Burn (LB/Hr)	1,058	From Mfr. Data	
Total Duration at Full Fuel (Hours)	3.64	=Fuel Capacity/Fuel Burn Rate	
Cruise Duration after subtracting Loiter	3.00	=Total Duration minus Loiter Time	
Cruise Speed (Kts)	130	From Mfr. Data	
Cruise Range	389	=Cruise Duration x Speed	
Range /2 (Out & Back)	**195**	=Cruise Range / 2	**Chart Value**

Super Puma	Data	Notes	
Maximum Gross or Max TO Weight:	18,960	From TCDS	
Aircraft Max Fuel Capacity	3,850	From TCDS	
Empty Weight	9,480	From Mfr. Data	
Crew (3@220 LBS)	660		
WP Gel Pump/Igniter System (Est.)	500		
Payload Available for Gel Fuel	4,470	= GW minus fuel, crew, EW & pump	
Calculated Gel Fuel (gallons)	447	=Payload Wt. divided by 10	
Gel Fuel Quantity (Lesser of calc amount or 1000 gal)	**447**	MIN Function picks lesser value	**Chart Value**
Loiter Time (Hours)	0.45	@1000gph, Used in Range Calc.	
Fuel Burn (LB/Hr)	1,058	From Mfr. Data, or calculated	
Total Duration at Full Fuel (Hours)	3.64	=Fuel Capacity/Fuel Burn Rate	
Cruise Duration after subtracting Loiter	3.19	=Total Duration minus Loiter Time	
Cruise Speed (Kts)	130	From Mfr. Data	
Cruise Range	415	=Cruise Duration x Speed	
Range /2 (Out & Back)	**207**	=Cruise Range / 2	**Chart Value**

Columbia 234 Chinook	Data	Notes
Maximum Gross or Max TO Weight:	48,000	From TCDS
Aircraft Max Fuel Capacity	14,000	From TCDS
Empty Weight	15,060	From Mfr. Data
Crew (3@220 LBS)	660	

WP Gel Pump/Igniter System (Est.)	500		
Payload Available for Gel Fuel	17,780	= GW minus fuel, crew, EW & pump	
Calculated Gel Fuel (gallons)	1,778	=Payload Wt. divided by 10	
Gel Fuel Quantity (Lesser of calc amount or 1000 gal)	**1,000**	MIN Function picks lesser value	**Chart Value**
Loiter Time (Hours)	1.00	@1000gph, Used in Range Calc.	
Fuel Burn (LB/Hr)	2,675	From Mfr. Data	
Total Duration at Full Fuel (Hours)	5.23	=Fuel Capacity/Fuel Burn Rate	
Cruise Duration after subtracting Loiter	4.23	=Total Duration minus Loiter Time	
Cruise Speed (Kts)	130	From Mfr. Data	
Cruise Range	550	=Cruise Duration x Speed	
Range /2 (Out & Back)	**275**	=Cruise Range / 2	**Chart Value**

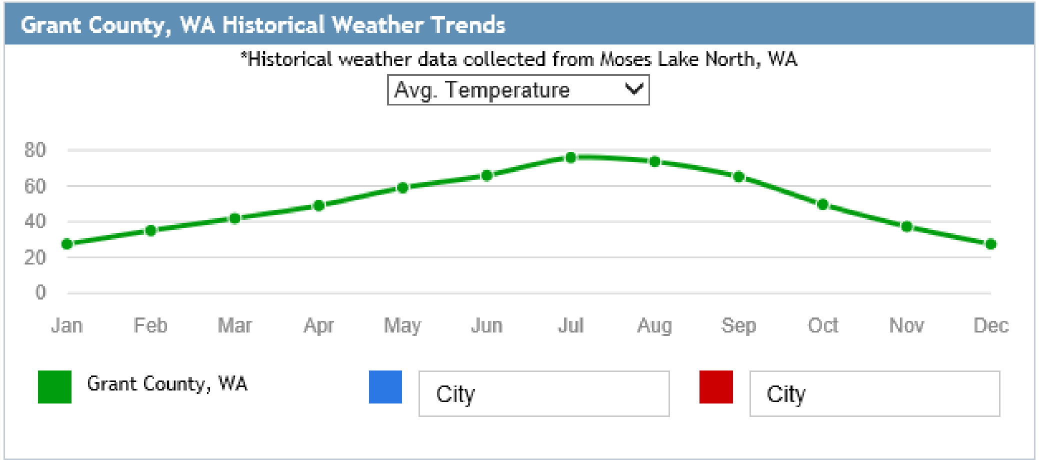
AW139	Data	Notes	
Maximum Gross or Max TO Weight:	14,110	From TCDS	
Aircraft Fuel	2,000	From TCDS Max 3,645	
Empty Weight	8,400	From Mfr. Data	
Crew (3@220 LBS)	660		
WP Gel Pump/Igniter System (Est.)	500		
Payload Available for Gel Fuel	2,550	=GW minus fuel, crew, EW & pump	
Calculated Gel Fuel (gallons)	255	=Payload Wt. divided by 10	
Gel Fuel Quantity (Lesser of calc amount or 1000 gal)	**255**	MIN Function picks lesser value	**Chart Value**
Loiter Time (Hours)	0.26	@1000gph, Used in Range Calc.	
Fuel Burn (LB/Hr)	700	From Mfr. Data	
Total Duration at Full Fuel (Hours)	2.86	=Fuel Capacity/Fuel Burn Rate	
Cruise Duration after subtracting Loiter	2.60	=Total Duration minus Loiter Time	
Cruise Speed (Kts)	130	From Mfr. Data	
Cruise Range	338	=Cruise Duration x Speed	
Range /2 (Out & Back)	**169**	=Cruise Range / 2	**Chart Value**

AW189	Data	Notes	
Maximum Gross or Max TO Weight:	18,292	From Mfr. Data	
Aircraft Fuel	2,000	FromTCDS Max 3,646	
Empty Weight	11,800	From Mfr. Data	
Crew (3@220 LBS)	660		
WP Gel Pump/Igniter System (Est.)	500		
Payload Available for Gel Fuel	3,332	= GW minus fuel, crew, EW & pump	
Calculated Gel Fuel (gallons)	333	=Payload Wt. divided by 10	
Gel Fuel Quantity (Lesser of calc amount or 1000 gal)	**333**	MIN Function picks lesser value	**Chart Value**
Loiter Time (Hours)	0.33	@1000gph, Used in Range Calc.	
Fuel Burn (LB/Hr)	1,054	From Mfr. Data	
Total Duration at Full Fuel (Hours)	1.90	=Fuel Capacity/Fuel Burn Rate	
Cruise Duration after subtracting Loiter	1.56	=Total Duration minus Loiter Time	
Cruise Speed (Kts)	150	From Mfr. Data	
Cruise Range	235	=Cruise Duration x Speed	
Range /2 (Out & Back)	**117**	=Cruise Range / 2	**Chart Value**

Sikorsky S-92	Range (1 way)	0	195	195	195
	Gel Fuel Qty	643	643	0	0
Super Puma	Range (1 way)	0	207	207	207
	Gel Fuel Qty	447	447	0	0
Columbia 234 Chinook	Range (1 way)	0	275	275	275
	Gel Fuel Qty	1,000	1,000	0	0
AW139	Range (1 way)	0	169	169	169
	Gel Fuel Qty	255	255	0	0
AW189	Range (1 way)	0	117	117	117
	Gel Fuel Qty	333	333	0	0

ATTACHMENT 3

Moses Lake, Grant County Airport, WA



USGS 1996 orthophoto

IATA: MWH – **ICAO**: KMWH – **FAA LID**: MWH

Summary	
Airport type	Public
Owner	Port of Moses Lake
Serves	Grant County, Washington (Primarily Moses Lake)
Elevation AMSL	1,189 ft / 362 m
Coordinates	47°12′31″N 119°19′09″W
Website	PortOfMosesLake.com

Map

Location of airport in Washington

Runways

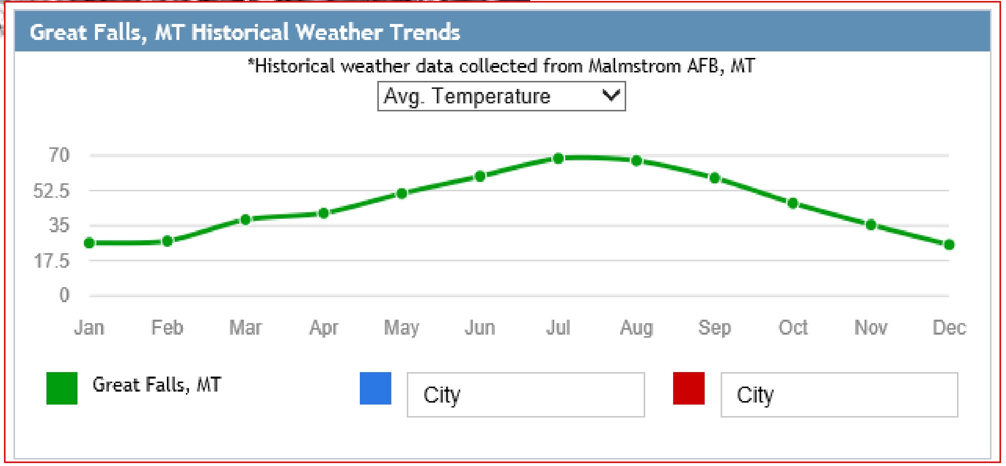
Direction	Length		Surface
	ft	m	
14L/32R	13,503	4,116	Asphalt/Concrete
4/22	10,000	3,048	Asphalt/Concrete
9/27	3,500	1,067	Concrete
18/36	3,327	1,014	Asphalt
14R/32L	2,936	895	Concrete

Statistics (2010)

Aircraft operations	63,315
Based aircraft	37

Source: Federal Aviation Administration[1]

Malmstrom Airbase, MT



Coordinates	47°30′17″N 111°11′14″W
Site information	
Controlled by	United States Air Force
Site history	
Built	1941
In use	1941 – present
Garrison information	
Garrison	341st Missile Wing

Airfield information

IATA: GFA – ICAO: KGFA – FAA LID: GFA

Summary	
Elevation AMSL	3,472 ft / 1,058 m
Coordinates	47°30′17″N 111°11′14″W
Website	www.malmstrom.af.mil

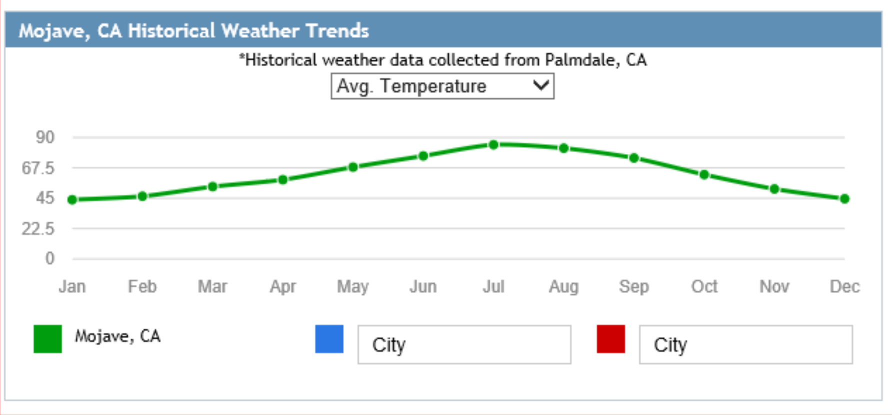
Map

Location of Malmstrom Air Force Base

Helipads

Number	Length		Surface
	ft	m	
H1	100	30	Asphalt

Mojave, CA



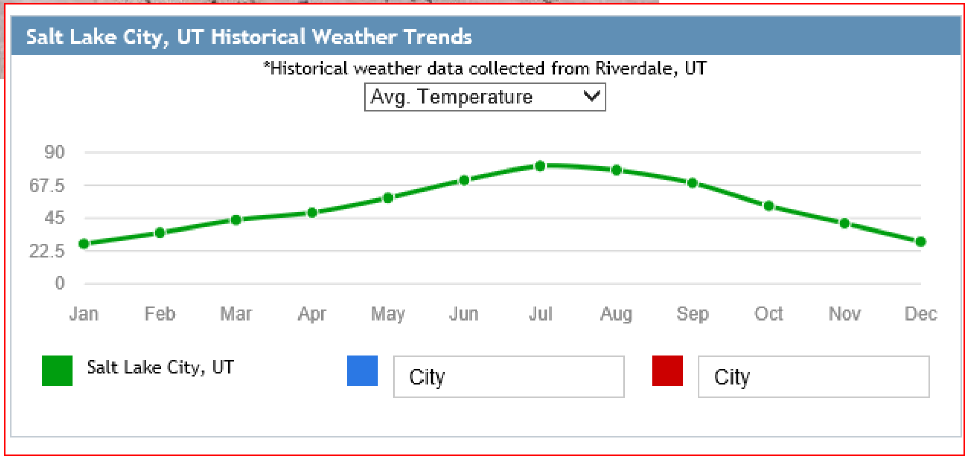
IATA: MHV – ICAO: KMHV

Summary	
Airport type	Public
Owner	Airport District,
Operator	East Kern Airport District, Mojave CA
Location	Mojave, CA
Elevation AMSL	2,801 ft / 854 m
Coordinates	35°03′34″N 118°09′06″W
Website	mojaveairport.com

Runways			
Direction	Length		Surface
	ft	m	
12/30	12,503	3,811	Asphalt/Concrete
08/26	7,049	2,149	Asphalt
04/22	4,746	1,447	Asphalt

Mojave spaceport

Bonneville Salt Flats, Ut.



Bonneville Salt Flats Race Track

U.S. National Register of Historic Places

Phoenix Diesel Truck running at the Bonneville Speedway

Nearest city	Wendover, Utah
Area	36,650 acres (14,830 ha)
Built	1911
NRHP Reference #	75001826[1]
Added to NRHP	March 16, 1984