The Evolution of a Dispersant Spraying Platform from Turboprop to Jet Engine Aircraft

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ABSTRACT

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As a result of a successful modification to an Oil Spill Response Limited Boeing 727 aircraft (registration G-OSRA) to enable aerial dispersant spraying, a paper has been written, aiming to provide an insight into the introduction of a turbine aircraft dispersant-application platform and the implications of the evolution from turboprop to jet engine aircraft. Furthermore, Oil Spill Response Limited has recently commissioned and introduced a second aircraft of the same modification specification (registration G-OSRB).

As a response technique, dispersant application can have a significant impact on tackling large quantities of oil at sea; however, much of its effectiveness relies on targeting the oil during the window of opportunity in which dispersant will work successfully, in the early stages of the weathering processes.

Time is, therefore, a critical factor and it is this key aspect, as well as others explored in detail throughout the paper, that led to the development of a pioneering system, specifically designed to respond to oil spills, that will undoubtedly prove to have a positive impact in terms of response times to incident sites.

The paper also presents the reasons supporting the choice of a Boeing 727-2S2F (RE) aircraft as the chosen platform for dispersant spraying operations, such as the power to weight ratio, cargo capacity, and rearward mounted engine positions, to name but a few.

It is also important to analyse the benefits of the Boeing 727-2S2F (RE) and the dispersant spraying system it contains during the different stages of the incident life cycle, be it during the preparation phase or the response phase. In the preparation phase, one of the advantages to highlight is the resilience of having two aircraft operated under a back to back schedule of maintenance as envisioned by a maintenance program specially designed to ensure continuous operational availability. During the response phase, aircraft such as G-OSRA and G-OSRB benefit from reduced transit times to incident sites due to the higher speed through the air that is possible with jet aircraft. Also, the paper also compares some key performance indicators such as range and speed between the turboprop aircraft of choice, Hercules L-382 and the Boeing 727-2S2F (RE).

INTRODUCTION

The concept of chemical dispersion as a response technique and the use of dispersants to achieve it is not new. Dispersant research and product development has been on- going for decades with the goal of obtaining more effective, low toxicity products. The industry has reached several milestones such as developing and perfecting vessel mounted application systems; improved dispersant formulations for effectiveness, given that oil is still amenable to dispersants, and most importantly for the focus of this paper the development and evolution of dispersant spraying equipment to be mounted on aircraft.

For decades now, turboprop aircraft like the Hercules L-382 have proved their value as a dispersant spraying platform in significant incidents, most recently in the Gulf of Mexico during the Macondo Incident. It is estimated that of the 6.8 million litres of dispersant used during the incident, 3.9 were sprayed either by vessels or aircraft. (Wilson et al., 2016)

Although highly effective at dispersant spraying operations, the use Turboprop aircraft poses numerous challenges, as highlighted and later discussed by the IPIECA-IOGP Oil Spill Response JIP finding 14 (JIP 14), such as aging aircraft, relatively low transit speeds of turboprop aircraft, and difficulty to obtain flying permissions to transit through certain air spaces due to ex-military status of some spraying aircraft.

With the findings of the JIP 14 in mind, Oil Spill Response Limited (OSRL) has developed a state of the art dispersant spraying system specifically designed to be used by jet engine aircraft from the designing stages, through prototyping, system testing, and finally service integration into OSRL response capabilities. The aircraft of choice in this instance has been the Boeing 727-2S2F (RE), a particular type of the Boeing 727 model which will be discussed in detail in the upcoming sections of this paper. Purposely called TERSUS, this system has been named after the Latin word for clean-up.

With new capability in place, it is necessary to make a brief comparison between previous spraying systems and aircraft and the new system and aircraft of choice. For comparison, Table 1 displays the main specifications for the Hercules L-382 with NIMBUS system and the Boeing 727-2S2F (RE) with TERSUS system.

	Hercules L-382 with NIMBUS system	**Boeing 727-2S2F (RE) with TERSUS system**
Transit Speed (knots)	300	480 270[1]
Spray Speed (knots)	150	150
Mobilisation time for dispersant spray operations	5 hours	4 hours
Air Crew	4	3
System capacity (Litres)	12,000	15,000
Minimum Runway length required (Feet)	4900	6000
Cargo Payload if spray system removed (Tonnes)	21	25.707
Flow rate (Litres/minute)	1300	1200

Table 1 - Hercules L-382 with NIMBUS and Boeing 727-2S2F (RE) with TERSUS

[1] Transit Speed if spray booms fitted.

From the outset, it is evident that jet engine aircraft such as G-OSRA can travel at greater speeds thus reducing the transit time to the incident site. Furthermore, it has greater payload. Mobilisation time between the two aircraft being examined has also been reduced by 1 hour in the case of the jet aircraft, due to the fact that the operator of the TERSUS system has put in place standard operating procedures that were designed to make mobilisation time as brief and time effective as possible. In addition, the TERSUS system is kept permanently installed in G-OSRA and G-OSRB, a time saving feature if compared with the NIMBUS system (modular system built for easy transport and installation into aircraft of opportunity).

DISCUSSION

TERSUS system

TERSUS is a modular system that comprises of 7 storage tanks with the capacity of 15,000 litres in total; a pump pallet that holds 2 centrifugal pumps and subsequent circulation circuit; a service pallet containing a flow meter that monitors fluid as it is pumped out of the pump pallet; a ventilation system that maintains constant air pressure in the TERSUS system and ventilates any vapours from the tanks; an air compressor and 2 spraying boom arms with 15 nozzles each as well as ancillary equipment and ground loading dispersant equipment, to describe it simply. TERSUS has been built with secondary containment capability, which means that should primary containment fail, this fail-safe feature will ensure dispersant is not released outside the TERSUS system and spilled inside the aircraft.

Figure 1 - Graphic Representation of the TERSUS System installed in the Boeing 727-2S2F (RE).

From an operational point of view, previous systems had system control panels that were located at the aft of the aircraft and required system operators to wear harnesses so as to be able to work near the aft door while this is open during spraying operations. The TERSUS design completely eliminates this practice, by integrating the system control within the flight engineer's panel within the cockpit. These are operated by the aircraft crew safely without the need to leave the cockpit.

Figure 2 - G-OSRA during a spraying exercise (water spraying, in this instance).

The system has been designed by aviation designers, which means that all materials used to produce the system are approved and rated for aviation use. This characteristic allows the possibility of the TERSUS system to be built or adapted at a later stage for the use in a different aircraft model with minimal adaptation. From an engineering point of view, the tanks have been designed to make use of as much space as possible to maximize the quantity of dispersant transported.

Regarding capacity, the system transports and delivers 15,000 L of dispersant in a single spray run. To ensure maximum aircraft stability, the aircraft must take off either with a full payload on the TERSUS system, or empty.

The system is approved for use with a variety of dispersants, namely the following:

- Agma DR379
- Corexit EC9527A
- Corexit EC9500A
- Finasol OSR 51
- Finasol OSR 52
- Slickgone LTSW
- Slickgone NS
- Superdispersant 25
- Inipol IP80

Corexit EC9500A, Slickgone NS, and Finasol OSR 52 products can be sprayed by the TERSUS system, which means that it is possible to utilise dispersant from the Global Dispersant Stockpile which features these same products. The Global Dispersant Stockpile is maintained by OSRL (Carter-Groves, 2014), enabling this new capability to be used to supply the TERSUS system during a response. In practical terms, this signifies a potential supply source of 5,000,000 L split between 6 locations worldwide already on stand-by for service subscribers (OSRL, 2016a).

Although its capacity is 15,000 L, it is possible to freight a larger quantity in different aircraft to the airport where the spraying aircraft will be stationed as oil spill response operations are on-going. Also important to note is that the weight of the dispersant on the system does not affect the airspeed of the aircraft, but due to the use of extra fuel, the aircraft range is reduced to 2250nm before needing to refuel (Prendergast and Jeans, 2016).

In the wake of 2 incidents of lateral oscillation reported by an aviation operator, Boeing Aviation Services issued a Service Letter applying to all Boeing aircraft for a limit on liquid cargo to 42% of the total cargo (Boeing Aviation Services, 2010). It is essential to clarify that even though both G-OSRA and G-OSRB are Boeing aircraft, due to its modified status approved by the European Aviation Safety Authority (EASA) Supplemental Type Certificate (STC), both are exempt from this Service Letter.

In regards to TERSUS parts availability, as the system is custom built for its purpose, many of the components that make part of the system have to be manufactured in accordance with the approved design data as conceived by the aviation designers and captured in technical drawings. The current aircraft operator was also involved in designing and producing the system, therefore manufacturing parts and components for TERSUS is not a problem.

It is important to highlight that the TERSUS system cannot be operated or modified by any other authority other than the flight crew or an aviation qualified engineer. In the event of a mobilisation an aviation engineer will be sent to meet the aircraft in country to maintain the aircraft and spray system during a response (Prendergast and Jeans, 2016).

Operational considerations of the modified Boeing 727s

It is equally important to consider the operational requirements that the B727 entails.

As with any other aircraft, G-OSRA and G-OSRB are under strict maintenance procedures designed to keep the aircraft airworthy for years to come. It expected that based on the current status, both aircraft have over 10 years service life expectancy as of 2016, based on current B727 parts availability; maintenance facilities certified to carry out work on B727s; and the 2 aircraft purchased, surpassing the 10 year expectancy predicted in 2012 for this type of aircraft (IPIECA-IOGP Oil Spill Response Joint Industry Project, 2012a).

Both G-OSRA and G-OSRB are B727-2S2F (RE) models. This specific model of B727 was designed with cargo transport in mind, as these aircraft were specifically built for FedEx, as part of a group of 15 airframes originally commissioned. The Pratt & Whitney JT8D-17A engines are more powerful than those used in previous models of the B727(16,000 lb thrust per engine, in comparison with 14,000 lb thrust on B727s equipped with JT8D-1 engines) (Department Of Transportation Federal Aviation Administration, 1991) and thus providing superior performance during take-off.

When the B727 was designed, in the 1960s, noise regulations applying to aircraft were still in its infancy. Since then, regulations have evolved and have well-established noise levels to which all commercial aircraft have to comply with. Both the Federal Aviation Authority (FAA) and EASA actively regulate noise emissions in the United States of America and Europe respectively. Both G-OSRA and G-OSRB are fitted with noise cancelling systems called hush kits in order to reduce the decibels emitted by the engines, allowing them to take-off and land without restrictions based on noise emission, as their engines emits below the maximum decibel threshold permitted for flyover (93.4 on a 95.5 dB limit) and approach (99.3 on a 101.1dB limit) emissions (EASA, 2016b).

Due to the nature of oil spill response, it is imperative that the system has close to 100% availability rate. However, this would be impossible to achieve if only one aircraft had been commissioned with the TERSUS system. Maintenance is of great importance, and once it is being carried out, it can take days until it is finished, depending on what kind of maintenance work is being conducted.

The operator of both aircraft, 2Excel Aviation, understands the urgency of oil spill response, and the readiness status that the aircraft must have, so therefore, the two aircraft are kept on a back to back maintenance program, allowing one to be down for maintenance while the other assumes the primary aircraft role.

Just as important as the dispersant system and the aircraft, the crew that flies these aircraft is a fundamental part of this dispersant-application platform. As previously mentioned, the aircraft is operated by an aircrew of 3 personnel, comprising of 1 pilot, one co-pilot, and a flight engineer. These highly skilled crews all have extensive relevant experience in flying jet aircraft at low level, high workload environments or been involved in aerial dispersant spraying operations with previous operators.

In addition, during spraying operations, an OSRL Task Specialist will also be present in the cockpit. Personnel that perform this role are selected from an operational oil spill response background, with first-hand knowledge and experience in spraying operations during the response phase of an incident. When conducting spraying operations, a task specialist is the link reporting to the Incident Command in regards to the operational details of the spraying activities being carried out. The Specialist will also log, record and report quantities of dispersant sprayed and where it was sprayed by utilising dedicated geo-referencing equipment and software.

Flight clearances were sometimes a hurdle for the Hercules aircraft, because some airframes had previously been military aircraft, and not every country would be keen to give it permission to cross their airspace (IPIECA-IOGP Oil Spill Response Joint Industry Project, 2012a). G-OSRA and G-OSRB do not face these constraints as both airframes have always had a commercial status, rather than military status.

The system has only recently been made operational, and further system testing is scheduled for 2017. However, spray runs carried out in September 2016 have demonstrated that the aircraft performs steadily during spraying speeds of 150 knots at an altitude of 150 feet.

Figure 3 - G-OSRA and G-OSRB during a spraying exercise (water spraying, in this instance)

Certification & Compliance of the modified 727s

The world of aviation is complex and ruled by the highest engineering safety standards, and with this in mind, it is necessary to give a brief overview of which aviation bodies were involved in the development of the system and which are still involved after certification has been granted.

As previously mentioned, both aircraft were formerly operated by FedEx as cargo freighters. At the time, both airframes were registered as American aircraft (G-OSRA was N-217FE, and G-OSRB was N-480EC) and complied with FAA regulations. However, when the aircraft were acquired by the current operator, the airframes were re-registered as British and from then on were under the regulations of the Civil Aviation Authority (CAA), the UK's aviation regulator; and EASA, the regulatory and executive agency in the field of civilian aviation safety in Europe.

For all intents and purposes, and although only a few modifications were required to the aircraft to accommodate the system, from a certification point of view, this is enough to consider that a modification has been carried out to the aircraft. The original type certificate (TC) holder for the B727 is Boeing as the original manufacturer under certificate number FAA A3WE (Department Of Transportation Federal Aviation Administration, 1991).

As such, an STC had to be sought after from EASA, in order certify the changes made to the design of the original TC. In May 2016 EASA STC number 10058044 was formally issued, attesting to the design change and describing it as the ‘Introduction of an Oil Dispersant Fluid Storage and Delivery System (TERSUS)’ (EASA, 2016a).

Regarding aviation organisations involved in the development of the TERSUS system, as it was developed in the UK, it was under CAA and EASA regulations. Because an STC would only be issued if the full development of the system was in accordance with EASA and CAA requirements, a careful selection of aviation companies and their approval status had to be considered before work on the prototype could commence.

As such, the TERSUS system was designed by a design organisation that holds a Design Organisation Approval complying with EASA Part-21 Subpart J. The Design Organisation would then pass the design data to the Production Organisation, in charge of building the prototype. The Production Organisation had to hold a Production Organisation Approval complying with EASA Part-21 Subpart G.

Once the STC for both aircraft was released, this meant that both could fully operate as intended, but by no means meant that the regulative requirements for approved bodies involved in the upkeep of the aircraft and systems had stopped.

Post- STC, the most important aviation approved bodies involved in continuing airworthiness are the maintenance organisations that must meet the requirements of EASA Part-145. These aeronautical repair stations are approved locations where aircraft can be serviced by competent personnel, following a well-documented set of procedures and carry out the maintenance program as established by the Continuing Airworthiness Management Organization (CAMO) of the aircraft operator.

CAMO, or sometimes referred to as EASA Part-M, is the industry body that is responsible for coordinating the compliance of aircraft with a maintenance program, airworthiness directives, and service bulletins.

From this brief overview, it is clear that the requirements of the aviation industry towards the safety and airworthiness of aircraft are very strict. The current operator of the system is an excellent choice to fulfill such role, because it was involved in the design and production of TERSUS while it was still a prototype but also, now that the system is operational, the operator possesses approved maintenance facilities and an airworthiness organisation to continue airworthiness. This unique insight from the system concept stages up to operational deployment and beyond is an advantage.

CONCLUSION

Several conclusions can be drawn from this paper. Firstly, that the introduction of the dispersant spraying system on a jet aircraft has been a groundbreaking project that required the involvement of several organisations to deliver new oil spill response capability to the industry. Secondly, the integration of the system as an operational asset has taken place, and further system testing is scheduled to be held in 2017, and from then more data will become available regarding TERSUS performance.

It is possible to conclude that the OSRL Tier 3 response aircraft fleet is in a transitional period, because as it stands in 2016, turboprop aircraft like the Hercules L-382 are still operating and performing as spraying aircraft, but new systems specifically designed for jet engine aircraft are now available and fully integrated as part of OSRL's response capability. It is therefore clear that a new milestone has been achieved in the industry.

Lastly, this paper has also concluded that the TERSUS system and the aircraft that to which it has been fitted are valuable assets for the industry. Its comprehensive upkeep will extend life expectancy based on the robust and strict safety and engineering standards it has been built and maintained to.

REFERENCES

Boeing Commercial Aviation Services, 2010. Transport of Liquid Cargo Service Letter. In: ATA: 0200-30. Boeing, Seattle

Carter-Groves (2014) Global Dispersant Stockpile: Part of the Industry Solution to Worst Case Scenario Readiness. International Oil Spill Conference Proceedings: May 2014, Vol. 2014, No. 1, pp. 504-515.

doi: http://dx.doi.org/10.7901/2169-3358-2014.1.504

Department Of Transportation Federal Aviation Administration, 1991. Type Certificate Data Sheet A3WE In: Revision 19 https://fas.org/man/dod-101/sys/ac/docs/a3we.pdf (Last accessed 10.12.2016)

EASA, 2016a. List of EASA Supplemental Type Certificates http://www.easa.europa.eu/download/stc/STC_WebList.xls (Last accessed 07.12.2016)

EASA, 2016b. Jet airplanes noise database https://www.easa.europa.eu/document-library/noise-type-certificates-approved-noise-levels (Last accessed 07.12.2016)

IPIECA-IOGP Oil Spill Response Joint Industry Project, 2012a. History and Current Status. In: Current Status And Future Industry Needs For Aerial Dispersant Application (Finding 14). Oil Spill Response Joint Industry Project, London

OSRL, 2016a. Global Dispersant Stockpile. In: Dispersants Technical Information Sheet. Oil Spill Response Limited, Southampton

Prendergast and Jeans, 2016. Pages 11-19. In: B727 Mobilisation and Logistics Plan. Oil Spill Response Limited, Southampton

Wilson, Larissa, Hale, Maung-Douglass, Sempier and Swann, 2016. In: Persistence, Fate, And Effectiveness Of Dispersants Used During The Deepwater Horizon Oil Spill. Gulf of Mexico Research Initiative. http://masgc.org/oilscience/oil-spill-science-dispersant-persis-fate-effect.pdf (Last accessed 14.12.2016)