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Reverse Engineering:

How to Reconstruct Aircraft Parts

BY MARINO BORIC

In the aerospace world, the procurement of spare parts is not always easy and is usually expensive, especially for older aircraft. At some point, when it comes to vintage aircraft, spare parts become rare, or in a worst case they simply don't exist anymore. A historically significant airplane disappears from the airfield and becomes in a best case a static exhibit in the museum.

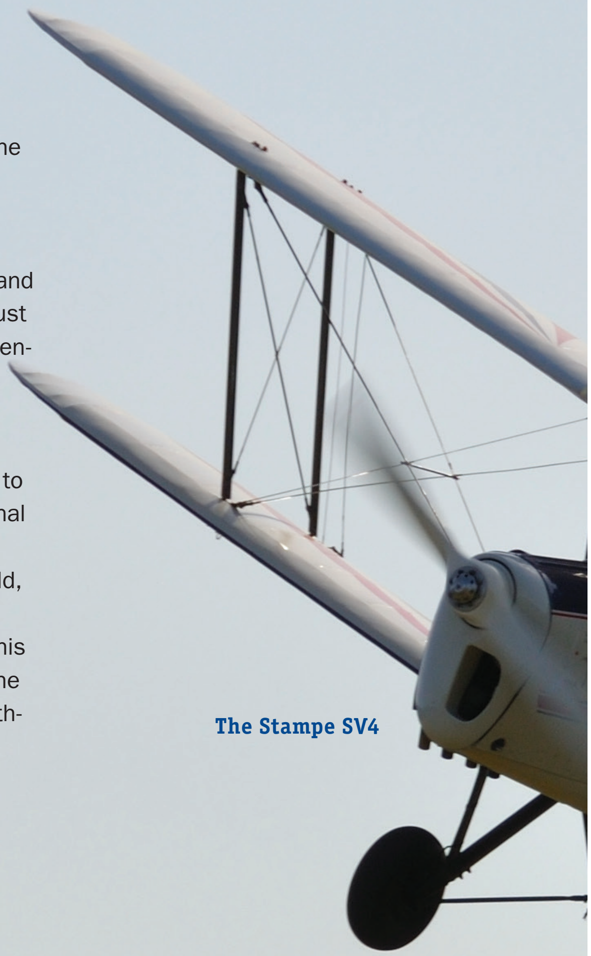
Today, with a help of reverse engineering technology the active life of such an airplane or entire fleet can be extended at a reasonable price.

Sheet metal parts are easier to reconstruct, engine parts, specially the big ones like engine blocks, are one much different and complicated story. This is mainly, because after decades casting molds don't exist anymore — usually the original manufacturer went out of business decades ago and a new series production is not feasible for reasons of cost. In this case, reverse engineering technology now helps to reconstruct parts. This process makes it possible to re-create a product, which exactly equals the original part, using an existing (broken) part, a piece of it, or a blueprint. In doing so, reverse engineering must go through a certain process, which includes the strategic consideration of how this "restoration" has to happen — where a specific succession of steps is required. This reverse engineering has many similarities with the design of a new part.

On the recovery path, from a damaged or no longer existing part, many problems have to be solved, because such a process is not simply a copy of the original part. Thanks to modern technologies such as 3-D scanning and new design software, almost everything has become "doable," even with much better properties than the original part. An improvement of the properties is usually not (always) desired in aviation, since the parts have to meet the original certification standards. If reverse engineering is used for the commercial reproduction of parts, extensive industrial property rights and the corresponding licensing laws must also be observed. Parts for experimental aircraft can be reproduced in better quality, can be lighter, and cheaper, since less legal standards have to be met. A certified part has to be restored according to OEM (original equipment manufacturer) specification, as the original part was. It could, however, also be improved by more modern technology/materials, but this has to be coordinated by and with the OEM and the aviation authorities, otherwise the certification may be lost.

In a concrete example, which I discovered at the last AirVenture in Oshkosh, I would like to explain the reverse engineering process. It does not always have to include all the described steps, some may be obsolete but sometimes some may be added — all taking into consideration the condition of the original part and many other factors.

This text describes a vintage airplane, engine crankcase remanufacturing done with a highly digitized process of two French companies: Ventana and Vintair. It is just an example of new remanufacturing possibilities offered



The Stampe SV4

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by the use of modern technologies and proven traditional skills. It can be used in many fields like mechanical parts, sheet metal, molded parts, etc.

The Stampe SV4 - Biplane

The Stampe SV4 is a French aviation milestone. The Stampe, a little biplane, is part of the French aviation heritage and is famous for having been widely used in army and civilian flying schools in late ‘40s and early ‘50s. 850 airplanes were built in 1946-47, as an after WWII war reconstruction effort. The Stampe was built in France under license, and is based on a Belgian design from 1936. Those French-built Stampes were equipped with a 145-hp Renault, four-stroke, four-cylinder, in-line engine. Stampe features nice aerobatic capabilities, delightful handling, and has become a myth in the French aviation community. More than 200 airplanes exist, and are close to, or in a flying condition.

Material Fatigue As the Life Limiting Factor

One of the most challenging problems to keep Stampes flying is to find spare aluminum crankcases for the Renault engine. In-service crankcases and the (rare) spares available have logged a considerable number of hours. Like all light alloys parts they are subject to cyclic loads, where material fatigue is limiting their life. Many of the inspected crankcases show fatigue cracks.

Metallurgic analysis of the crankcases showed poor mechanical resistance, caused by impurities and internal corrosion, making the welding repair highly uncertain.

Because of this, some users started to consider moving to another engine. This is a very costly option, and no other engine allows it to stay close to the appearance and handling of the historic Stampe. For those reasons it was decided to remanufacture the crankcase using Ventana’s new techniques and Vintair reverse engineering skills offering a historically correct solution to the part shortage.

This is a typical example of the new technological possibilities when it comes to parts shortage. It can be applied to any other complex part and the whole process follows this path: Digitization of the used part. Using a high-precision optical scanner, the visible surfaces of the existing engine block are scanned creating a cluster of points with an accuracy of 0.02 millimeters creating a very good start point for a complete CAD reconstruction. To capture hidden details, like internal cavities or ducts, tomography technique may be used — the same complex and costly technique used in a medical scanner. Dedicated software allows to interpolate missing surfaces and to re-create the details using original design principles and geometry. When the highest accuracy is needed, a 3-D measuring robot is used for the most sensitive areas.

3-D Model, Manufacturing Drawings Setup

Most of the time, the data acquired by the optical scanner cannot directly be used, and a thorough functional analysis should be performed, which often requires careful measurement of adjacent parts.

A major step in this process is the CAD model creation — made by using all data acquired in the digitization step. This is a real reverse engineering step where dimensions and tolerances are determined to allow the final assembly, taking into consideration the bearing alignment, gear axis matching, etc. If drawings/blueprints are available, they are used, adding useful information in this step.

In a case where no part and/or drawing is available, a new design can be established by using all available clues like pictures, location of adjacent parts, and a functional analysis.

Usually, when the material has been in service for many years, users will know the weakness areas of the part. While staying close to the original design, improvements may be introduced by using better suited alloys or slightly changing the geometry. This improvement process likely requires an approval of local aviation authorities through a minor or major modification

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request. As Stampe belongs to EASA Annex II aircraft list, this is done under French Civil Aviation Authority (DGAC) and the mod approval is granted to each aircraft owner.

Material Analysis

In a case that the original material/alloy is not known a mass spectrometer is used. Yield samples are used to assess the mechanical resistance of the material. This analysis allows the choice of the closest alloy amongst referenced materials. For this Renault crankcase — as no exact material match was found — a high resistance aluminum alloy was chosen. This is animprovement but only possible for vintage planes under EASA Annex II rules, and under the owner's responsibility.

Casting, Solidification Simulation

The crankcase is a sand casting made product, so the following step is performed in a foundry.

Once validated, the CAD model is directly used to design the casting mold. In this process a new simulation software is used, which helps to predict molten metal flow in the mold, temperature gradients, and metal shrinkage. This software simulation allows to avoid real-life testing and dramatically reduces development costs and time.

This phase ends with the sand casting mold design, where extensive foundry know-how is necessary, specially for parts with thin walls or relevant variations in wall thicknesses.

When drawings aren't available, a new design can be established by using all available clues like pictures, location of adjacent parts, and a functional analysis.

3D-Printing of Sand Cores

The cores which constitute the mold are then 3-D printed with a 3-D, S15 sand-printing machine. One layer of sand — to which one component of resin has been added — after another is applied on the "job box" a vertically moving table. Each layer of sand/resin is then polymerized — sprayed by a "print head" with a catalyst component — that binds the sand to a solid structure in a required form. When the mold is printed, the loose sand is mechanically removed (air blasted, brushed away) and the different cores are assembled to make the final mold.

When using this fully digital, toolless process, complexity is no more a determining factor. Any part that has been cast can be easily remanufactured. 3-D sandprinting allows a high degree of shape complexity.

Sand printing of the mold sand cores is done by additive layer deposit (ALD) or additive manufacturing (AM).

It works like a big "jet printer" working over a vertically moving (lowering) flat "job box."

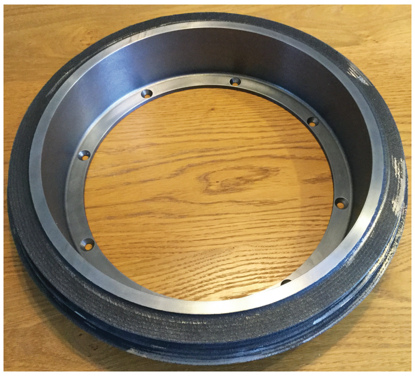
A thin layer of sand is spread on the job box. This sand has been previously mixed with one of two components of a special resin. The sand thickness may vary between 0.3 and 1 mm, depending on the accuracy and speed required. The process is very sensitive to the type and amount of resin, and very specific sand is used, which allows a controlled thickness and granulometry of the layer. This is a part of Ventana's know-how, that has been developed through a long setup, to be applied to widely used aeronautical magnesium- and aluminum-based alloys.

This thin layer of sand is then sprayed through the printer head with the resin's catalyzer to build up the core where the sand has to remain solid. The loose sand that has not been sprayed is kept in place during the process to support the next layers and allows vaults and arch type geometries to be easily built.

This iterative cycle is repeated until the cores are completely built.

Multiple imbricated cores can be printed during the same session, permitting the full box volume use and reducing the (expensive) sand losses.

JU52 original brake drum.



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The mold is usually printed in several parts to allow a perfect cleaning (loose sand removal) and assembled before pouring.

After each layer has been sprayed, the box lowers from the sand layer thickness, and another layer spreading and spraying cycle is started.

Printing can last from several hours to one or more days depending on multiple factors like requested accuracy, cores volume, etc.

Casting

Molten metal is poured into the mold on a low-pressure casting station via a complex feeding network that ensures the integral filling of the mold.

Once the mold has cooled down, it is shot blasted to remove the remaining sand from the metal part, and the feeding network is cut away.

Inspection

The part then follows an inspection process that includes geometrical digital scanning, radiography, and other checks. The process is similar to the one used for the aeronautical jet engine parts manufactured by Ventana.

Heat Treatment

To achieve the desired mechanical properties, light alloys are heat treated.

Through this process, as it is identical to traditional foundry, the mechanical properties and resistance are strictly identical to a casting that would have been obtained through a traditional (not 3-D) pattern casting.

Testing

The complete range of NDT (non-destructive testing) is being implemented, from X-ray to automated (PT) fluorescent dye penetrating test — all according to the specifications of the contracting parties. Parts are checked for internal defects and correct metallurgical characteristics, all according to the specifications that are part of the reverse engineering process.

Mechanical Machining

The cast, if defect-free, is machined on fully digital, high-precision CNC machines at the Ventana facility with the help of data obtained in the digitization process.

If needed, high-precision line boring can be performed, in its own traditional engine machining shop. This can include main and rod bearings boring.

Cost and Time

The costs and time exposure are difficult to determine in most reverse engineering processes because those figures are influenced by a number of factors. This depends on the nature and complexity of the part to be restored and the quality of delivered/available original part and blueprints. This process uses costly equipment and requires considerable design and engineering effort. While costs are higher than those of original parts that were manufactured in large quantities with a high degree of industrialization, they are much lower than traditional methods for limited quantities as no specific tooling is required, and real-life casting testing is dramatically reduced. Traditional, negative forms are not necessary, which for large series can cost several hundred thousand dollars.

Cost level is a function of part complexity and size, as well as NDT and alloy requirements.

Cost is split between nonrecurrent reverse engineering and mold design costs, and part production cost. Lead time can vary from several weeks for simple parts to three to six months when complex reverse engineering is required; much faster than the standard foundry part development time.

AM of the above described part is somewhat simpler, since no molds are necessary. At a current cost of $500 per cubic inch of a structure, a motor housing would cost about $50,000 per piece, a lot more than this method.

So far, the absence of spare parts in the past meant a sure “death” of an aircraft. With this reverse engineering, the operational life of an historical aircraft can be extended at a manageable cost. Smaller batches are also affordable. The engine crankcase is only one example, a remanufactured brake drum of the Junkers JU52, which was no longer available, was also built. There are just a few similar projects in the USA and Europe that will lead to whole aircraft in the next two to three years with the use of reverse engineering.

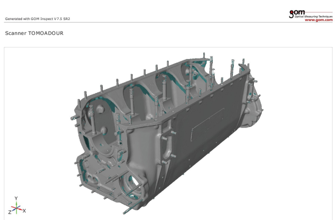
Currently the maximum possible size of a part depends on the dimension of a job box what still limits the production of some parts. Software and testing techniques must also be further developed and adapted. So far, there are only a handful of companies in the world that use this method. With the fast growth of 3-D printing technologies and machines, this will hopefully change soon. ■

MARINO BORIC has degrees in aeronautic engineering, business development/trade and commerce and in journalism. He is a civil and military pilot and has built experimental aircraft.

Ventana and Vintair

A Renault engine housing is being remanufactured for a Stampe SV4 airplane, with French certification. In this example, the French companies Ventana and Vintair cooperate and manufacture a crankcase using a highly digitalized process.

Ventana is a major French aerospace subcontractor. With its four foundry facilities, high precision machining and sheet metal capabilities, Ventana serves customers worldwide, including Airbus, Rolls-Royce, and Pratt & Whitney.



Vintair is a small company dedicated to vintage and collection aircraft. It specializes in restoration of vintage engines and has developed reverse engineering skills useful in that field.

For more information visit www.vintair.com or www.ventana-group.eu.

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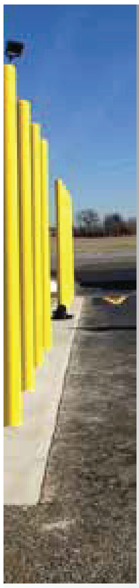

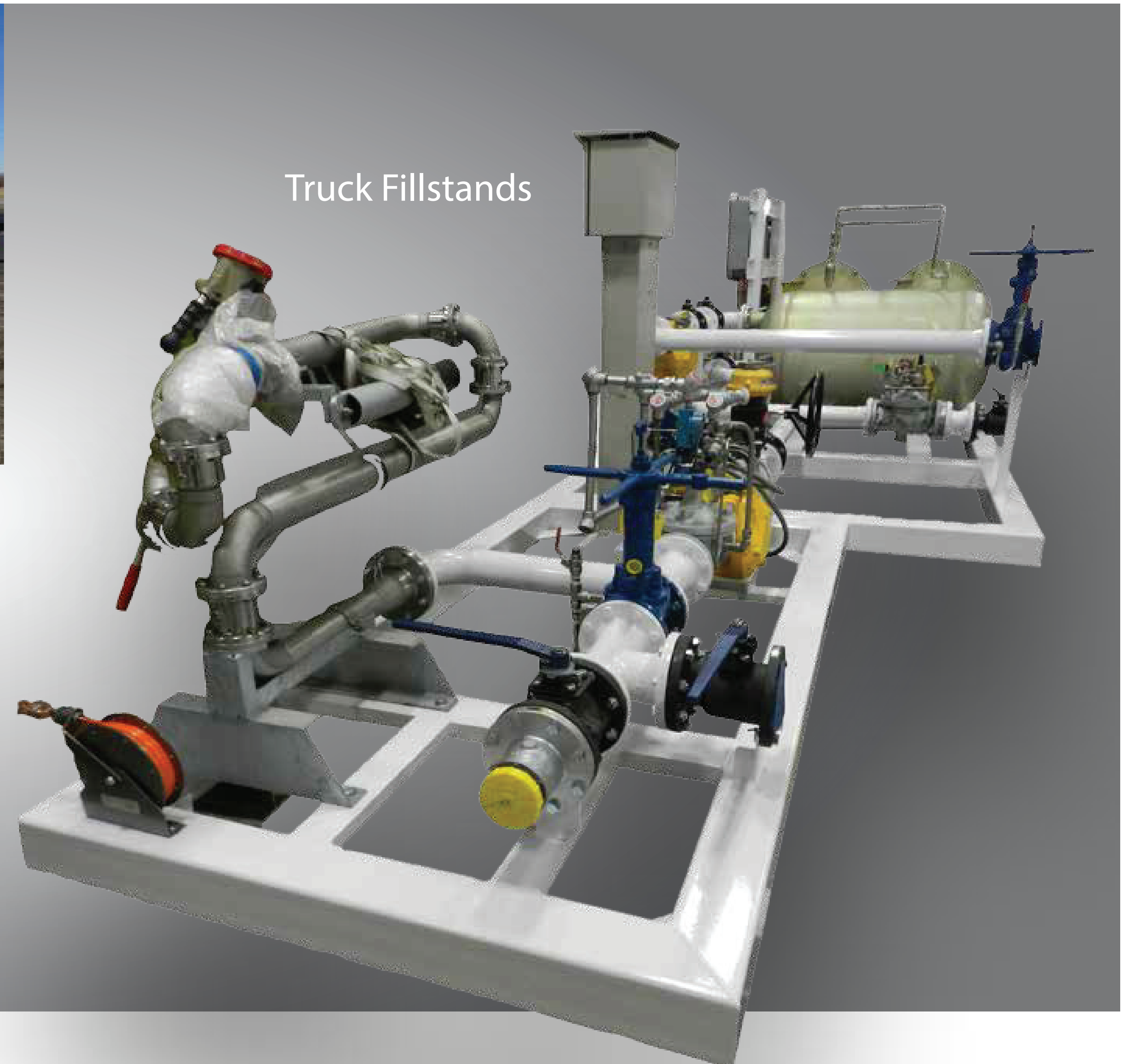

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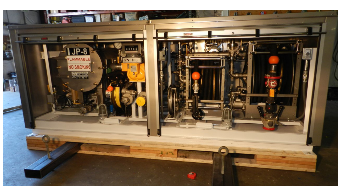

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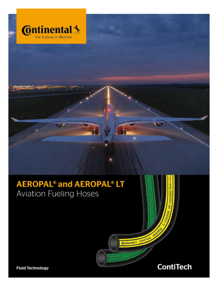

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Runway Sweeper

THE FOD CONTROL CORPORATION

The FOD-Razor Airport Runway Sweeper provides military airfields with a fast and efficient solution for ramp and runway debris. Durable construction, streamlined hitch assembly, superior design and highly competitive pricing. Easy to roll up and store when not in use. Highly portable for deploying overseas. Manufactured in the USA and shipped worldwide. Guaranteed with a 30-day money-back guarantee and lifetime limited warranty. For more information visit www.fodcontrol.com or call (800) 425-8363 or (520) 760-7732.

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Inspection Camera System

INTERTEST INC.

Inspect aircraft component surfaces with white and UV illumination using the iShot SeeUV 1.0-inch UV PoleCam 1000 FPI Camera System. Combined with a high-resolution CCD camera sensor, a 1-inch OD aluminum pole and interchangeable direction of view adapters (0, 45, 60 and 90 degrees), the PoleCam 1000 ease-of-use and versatility make aircraft fluorescent and white light inspections efficient and thorough. For more information call (908) 496-8008 or visit www.intertest.com.

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Control Room Consoles

IMAGEVISION INC.

ImageVision is a trusted supplier of control room consoles for airports, aerospace, defense companies and commercial airlines. Experienced in configuring control room furniture for a range of applications in aerospace and aviation industry, including security operations, baggage handling, aircraft maintenance, air traffic control, satellite tracking and space travel. ImageVision has helped organizations like NASA, Delta Air Lines, Gulfstream Aerospace, Lockheed Martin and General Dynamics improve performance of their control room operations with durable, modular and ergonomic workstations. For more information call (888) 664-6762 or visit www.imagevisionconsoles.com.

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Hand Pump Cart Dispenser

FLUIDTRAN INC.

The FLIGHTMASTER 2-gallon hand pump cart dispenser manufactured by FluidTran Inc. has a long history of use in commercial and military aviation. This equipment is adaptable to numerous attachments, improves safety and will provide years of reliable service. Each dispenser is hand assembled and fully tested to meet customer specifications. Contact E2 Associates LLC and ask about our small minority-owned or disadvantaged supplier options for best pricing. For more information visit www.fluidtran.com or call Reid Erickson at (276) 322-4353.

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Organize Your Tools

GRYPSHON LLC

Thanks to the Grypmat, tool users can focus on their work without having to worry about runaway screws or misplaced hardware. Due to its unique polymer-silicone blend, the Grypmat's grip can hold tools at extreme angles (up to 70 degrees) on a variety of work surfaces, making it the ultimate companion for working on aircraft wing, engines and fuselage. The Grypmat is resistant to all types of chemicals, such as Skydrol, MEK, JP8, hydraulic fluid, etc. and if it gets dirty, soap and water will make it as good as new. Grypmat's versatility and ease of use makes it an essential tool for trade professionals, mechanics, and DIYers alike. The Grypmat Original is currently available on the website. The three new Grypmat sizes are available for preorder on Indiegogo.

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Drain Guard

INLAND TECHNOLOGIES INTL. LTD.

Inland's Guard is an under-grate drain block valve designed to prevent liquids from reaching stormwater systems. It is used to contain spent aircraft deicing fluid and fuels. Because of its design, it is virtually impervious to freezing. Under normal conditions, the Guard is opened for uninterrupted stormwater flow. In the event of a spill — or as a preventative containment measure — the valve can be sealed within seconds. For more information visit www.inlandgroup.ca/glycolguard.php.

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Central Alaska Metalworks Inc. introduces a

FAST & EASY

Solution for ice & snow removal from airfield lighting canisters

In the field of aviation, whether civil or military, cold weather climates present significant challenges for the personnel charged with maintaining airfield lighting systems. Fully functioning airfield lights can mean the difference between life and death. Nowhere is this truer than in Alaska's rural towns and remote villages, the majority of which are accessible only by air. When there's a medical crisis, emergency aircraft depend on an airport with working lights. Shutting down an airport because of runway light failure caused by ice-filled in-pavement runway lights is not an option.

The ThawHead™: Grand Prize Winner of the 2015 University of Alaska Arctic Innovation Competition

HISTORY

In Alaska and other Northern climates, airport maintenance personnel face extreme cold and short days. Repairing ice-filled light canisters in such harsh conditions can be miserable work. When the Alaska Department of Transportation, Northern Region, decided to procure equipment or a "system" that enabled more efficient winter lighting maintenance and repairs at Alaska's rural airports, they went to Cameron Gackstetter of Fairbanks Alaska. Cameron had expertise in building custom equipment and a reputation for "thinking outside of the box." They needed a portable, self-contained unit small enough to be reasonably transportable to Alaska's rural airports in the winter.

CENTRAL ALASKA METALWORKS, INC.
PO Box 80300 | Fairbanks, Alaska 99708 |
(907) 474-4037 | central.alaska.metalworks@gmail.com

Central Alaska Metalworks CAM Inc.

Find us on YouTube- search "ThawHead"

The Thaw Rig™

PROBLEM

When airfield runway lighting systems fail during the winter, access to wiring and transformers inside the lighting base “cans” is frequently impossible because they’re filled with ice and frozen debris. The ice can be chipped out, but it may damage canister components. This lengthy, tedious operation also exposes maintenance personnel to frigid temperatures for substantial periods of time.

SOLUTION

At 40 inches tall, 11 inches in diameter and less than 40 pounds, The ThawHead™ is a portable apparatus that, when connected to a standard pressure washer, is placed on top of the exposed, ice-filled canister. Phase one, the thawing stage, directs targeted jets of high-pressure hot water through nozzles in the base of The ThawHead™ to break up the frozen material. Rotation of the apparatus, combined with adjustable water pressure, allows the operator to control the thawing rate as desired. Phase two, the evacuation stage, involves moving the base of The ThawHead™ off to the side, detaching the evacuation wand and inserting it into the melted slurry. Through a unique vortex action, the slurry is swiftly suctioned out through the discharge hose to the designated area or receptacle. Total time to empty an ice-filled canister averages 15 minutes: a significant improvement over current methods.

Designed for use in cold climates, The Thaw Rig™ is the optional self-contained support system for The ThawHead™. Within this trailer’s well-insulated walls are the pressure washer, generator, water pump, electric heater, battery charger, polyethylene water tank, antifreeze storage tank and The ThawHead™ apparatus itself. Designed to be towed behind an ATV or a snowmobile, The Thaw Rig™ generates its own heat and electricity. The complete unit fits in a CASA cargo airplane rear door.

Adjustable Maintenance Platform

EASY ACCESS INDUSTRIAL DESIGN INC.

Scissor Deck height adjustable aluminum maintenance platforms fold flat to 10 inches with 4-, 5- or 6-foot deck lengths. Deployable models have removable lower leg frames for even tighter cargo holds. Choose from five model sizes with stand or wheeled units. Height adjustability to 30 inches with max deck heights to 9 feet 8 inches. OSHA compliant with 500-pound rating for two workers. Designed, safety certified, developed and manufactured in Canada. For more information visit scissordeck.com, email scissordeck@shaw.ca or call (877) 730-2704.

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Optics for Drones

MELLER OPTICS INC.

Meller Sapphire Optics for drones include flat windows and domes for all types of vision systems used for inspecting military surveillance applications. Featuring Moh 9 hardness which is second only to diamond, highly durable and clear sapphire can withstand fast moving dirt, particulates, sand and water. Providing up to 85 percent transmission uncoated in the UV to IR, with up to 99 percent when A/R coated in two sides, Meller Sapphire Optics can be supplied with surface finishes from 60-40 to 40-20 scratch-dig and flatness held to 1/10th wave in the visible and < 2 arc sec. in/in parallelism per MIL-PRF-13830, depending upon configuration, with precise edge steps and mounting profiles. For more information call (800) 821-0180 or visit www.melleroptics.com.

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Nonhazardous Stripper

SOLVENT KLEENE INC.

D-Zolve 15-33 IM from Solvent Kleene Inc. is an immersion grade paint remover that meets the chemical requirements for safely removing coatings from aircraft wheels, landing gear components and other support equipment parts. Immersing parts in D-Zolve removes several layers of a difficult to strip epoxy, flexible polyurethane, polyurethane topcoat, or fluid resistant coating. D-Zolve 15-33 IM fully conforms to T.O. 1-1-8 and meets the specifications set by USAF Mil PRF.83936C. It has passed the corrosion, flammability, hydrogen nonembrittlement, and paint removal performance standards set by this specification. It is available in both 55-gallon drums and 5-gallon pails. For more information call (978) 531-2279 or email sales@solventkleene.com.

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Flame Detector

DET-TRONICS

Protect aircraft in hangars with the X3301 Multispectrum Infrared Optical Flame Detector. Traditional thermal detection can't provide the speed of response needed in open or drafty areas such as hangars, where smoke and heat from a fire can dissipate and delay or even evade detection. The X3301 can detect a 2 foot by 2 foot fire from up to 235 feet (71.6 meters) away, enabling fast alarm notification. (Photo courtesy of U.S. Air Force.) For more information visit www.det-tronics.com or call (800) 765-3473 or (952) 941-5665.

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Cleanup Solution

ANDAX INDUSTRIES LLC

Containing and cleaning up a 50-gallon spill is no problem with the Andax Barrel Pacs. These Pacs are color-coded and feature matching equipment labels. Each barrel has an easy-open, level-lock lid and allows usage from one to four responders. Materials are contained in a UN/DOT approved all-weather drum and is SPCC plan compliant. Each Pac is packed full with sorbents, Sorb-Sox, pillows, gloves, goggles, barrier tape and disposal bags. The barrels are reusable, just order refills. For more information call (800) 999-1358 or visit www.andax.com.

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F-16 Crew Boarding Ladder

JETECHNOLOGY SOLUTIONS INC.

The F-16 Cockpit Boarding Ladder provides both pilot and co-pilot access to the F-16 aircraft. Walking surfaces are equipped with anti-skid surfaces to prevent slippage while boarding and exiting aircraft; only MIL Spec fasteners are utilized during assembly; and each unit is individually wrapped and packaged in its own crate. For more information, call (407) 673-1512, email design@jsiengineering.com or visit www.aircraftmaintenancestands.com.

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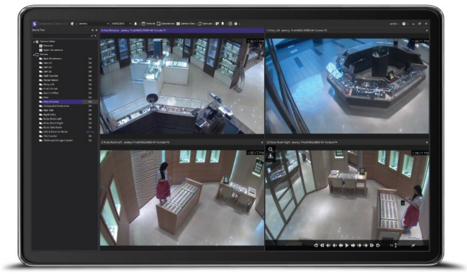

Video Management Software

AIMETIS SYMPHONY

Aimetis Symphony is the benchmark for intelligent video management software utilized by military bases and government offices around the world, including the 174th Fighter Wing Air National Guard in the United States. Symphony delivers industry-leading scalability, on-demand operational intelligence and flexibility. It's secure, easy to set up, and the only VMS with native video analytics. For more information call (519) 746-8888 or visit www.aimetis.com.

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Advanced Avionics Solutions

UNIVERSAL AVIONICS SYSTEMS CORPORATION

Universal Avionics provides advanced avionics solutions for all types of military rotor wing, turboprop and transport aircraft. The company's Flight Management System (FMS) and flight deck display upgrades address obsolescence issues, and equip aircraft for compliance with NextGen and industry mandates such as ADS-B Out. Modernizing military aircraft with Universal's emerging technologies allows for execution of critical missions in a safe, efficient and cost-effective manner. For more information visit www.uasc.com, call (520) 295-2300 or (800) 321-5253.

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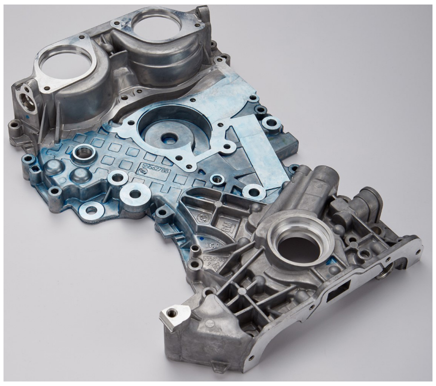
Polymeric Capillary Sealer

STRONGHOLD COATINGS



Stronghold Coatings introduces Blue Dichtol, the first polymeric capillary sealer for castings and composites that allows 100 percent visual inspection to ensure that porosity has been sealed. It impregnates micropores and hairline cracks without vacuum or pressure, forming a protective barrier to gasses and liquids that is not invisible when cured. Blue Dichtol penetrates deeply, (up to .004 inch), into the coating to prevent corrosion of the metal substrate. Pressure resistant to 8,700 psi, and temperature resistant to 932 F. Easily applied by dip, brush or spray, it dries in minutes and cures at ambient temperature. It significantly increases machinability and dampens vibration, to further enhance the utility of the components being treated. Approved for military use, NSN8010016541508, and made in the USA. For more information visit www.StrongholdOne.com or call (513) 808-1695.

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Ez Creeper

THE EZ CREEPER COMPANY, INC.

The Ez Creeper Company offers the aviation creeper. The hand-powered hydraulic device elevates and de-elevates "on-the-fly" without need to disembark. Sore knees and backs are a thing of the past. Productivity increases more than 11 percent. For more information call (810) 689-9997, (519) 452-1222 or email office@EzCreeper.com.

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