

# **Dust Tolerant Commodity Transfer Interface Mechanisms for Planetary Surfaces**

Robert P. Mueller<sup>1</sup>, Ivan I. Townsend<sup>2</sup>, Gabor J. Tamasy<sup>3</sup>

<sup>1</sup>NASA, Surface Systems Office, Kennedy Space Center, FL 32899

<sup>2</sup>ESC–Team QNA (Craig Technologies), Applied Sciences and Technology, Kennedy Space Center, FL 32899

<sup>3</sup>NASA, Structures & Mechanisms Design Branch, Mechanical Division, Kennedy Space Center, FL 32899

## **ABSTRACT**

Regolith is present on most planetary surfaces such as Earth's moon, Mars, and Asteroids. If human crews and robotic machinery are to operate on these regolith covered surfaces, they must face the consequences of interacting with regolith fines which consist of particles below 100 microns in diameter down to as small as sub-micron scale particles. Such fine dust will intrude into mechanisms and interfaces causing a variety of problems such as contamination of clean fluid lines, jamming of mechanisms and damaging connector seals and couplings. Since multiple elements must be assembled in space for system level functionality, it will be inevitable that interfaces will be necessary for structural connections, and to pass commodities such as cryogenic liquid propellants, purge and buffer gases, water, breathing air, pressurizing gases, heat exchange fluids, power and data.

When fine regolith dust is present in the environment it can be lofted into interfaces where it can compromise the utility of the interface by preventing the connections from being successfully mated, or by inducing fluid leaks or degradation of power and data transmission.

A dust tolerant, hand held "quick-disconnect" cryogenic fluids connector housing has been developed at NASA KSC which can be used by astronaut crews to connect flex lines that will transfer propellants and other useful fluids to the end user. In addition, a dust tolerant, automated, cryogenic fluid, multiple connector, power and data interface mechanism prototype has been developed, fabricated and demonstrated by NASA at Kennedy Space Center (KSC). The design and operation of these prototypes are explained and discussed.

## **INTRODUCTION**

Surface Systems on other planetary surfaces such as Earth's Moon, Mars, Mars moons, and asteroids consist of multiple elements that all must work together to perform the intended functions. Good systems engineering dictates that special attention should be paid to the interfaces between these elements. The interfaces deal with mechanical, structural, handling, electrical, radio frequency (RF), optical, data, commodities transfer issues and more. They often require special fittings or

couplings in order to mate one element to another. If they are all combined into an interface sub-system and mounted on a plate with handling, positioning, latching and structural loads transfer functions, then this is known as an umbilical system. The umbilical system typically transfers commodities from one element to another element such as power, electrical data, optical data, cryogenic propellants, water, grey water waste fluids, pneumatics, and coolant fluids for example. The reliability of these umbilical systems is paramount since they usually undergo multiple mate/demate operations and full systems functionality depends on sub-system interoperability via the umbilical interface.

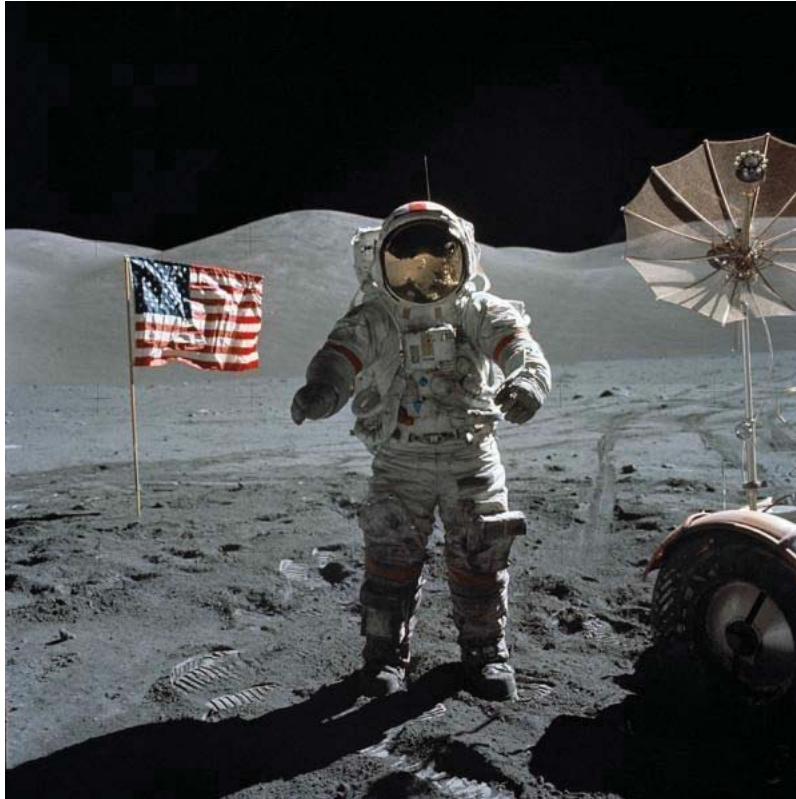


Figure 1: The surface of the Moon is covered in gray regolith powder dust that caused unforeseen problems for NASA astronauts. Apollo 17 astronaut Harrison "Jack" Schmitt took this picture of Eugene Cernan during their third and last walk on the lunar surface in December of 1972.

Planetary surfaces are extremely dusty places. They are covered with loose unconsolidated materials known as regolith. On the Moon this regolith is a deep layer of crushed rock with jagged edges and convoluted particle morphology created by high impact events over 4.5 billion years. These small particles are mostly sized under 100 microns in diameter and a 20% fraction is below 20 microns and sub-micron size (Heiken, 1991). On Mars, the dust has formed from geological weathering of rock formations and the particles are not as jagged as on the Moon, but are nevertheless extremely fine and dusty. Dust storms on Mars can cover exposed equipment with dust and impact its operation through contamination in various ways. On Asteroids, similar dusty conditions exist as the surfaces are covered with fine dust

that has accreted from the solar system debris of formation. If disturbed, this dust is lofted and can take a long time to settle down again since the micro-gravity of a typical Asteroid is only 1/1000<sup>th</sup> G.

These dusty conditions require that all connectors and interface umbilical mechanisms used on planetary surfaces must be protected from dust and the local environmental elements, to ensure reliable mating operations and subsequent commodity transfer.

#### **STATE OF THE ART OF CONNECTORS/UMBILICALS**

The conventional connector with protective dust barrier mitigates dust by incorporating a physical dust shield. These dust barriers may be retrofitted to existing commercial, military or International Space Station connectors. Alternatively, it is possible to utilize existing connectors that can be incorporated into a universal connector housing

#### **HAND HELD “QUICK DISCONNECT” CONNECTOR HOUSING**

A dust tolerant single connector protective housing was developed for cryogenic fluid and electrical connectors. This housing is designed to protect a single Commercial-Off-The Shelf (COTS) fluid or electrical “quick disconnect” connector. The connector can be installed into the housing with the cable or the fluid line exiting the handle of the housing, and the pins or poppet faces under the caps. To mate the connectors, the operator picks up one housing in each hand with the caps facing each other. The operator then opens the caps exposing the connectors by squeezing the levers. The two housings are then brought together in a twisting motion. The levers are then released. A seal on the housing prevents dust from accessing the connectors, and a seal on the caps prevents dust from contaminating the inner surfaces of the caps. To de-mate the connectors, the operator squeezes the levers again and twists the caps in the reverse direction. Once the housings are separated, the operator releases the levers allowing the caps to seal back to the housings.



Figure 2. Showing the Flip Cap Dust Tolerant Housing in Operation

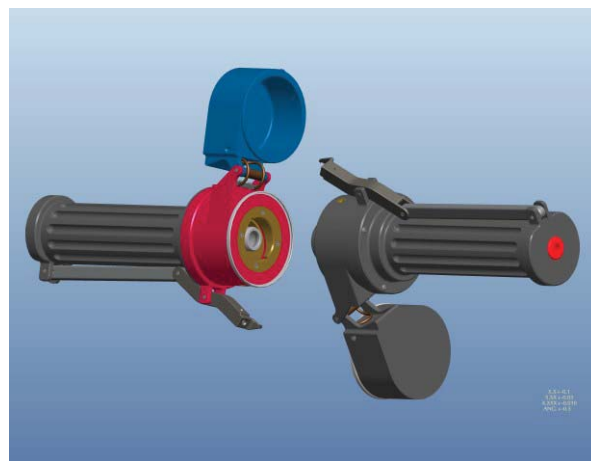


Figure 3. Concept Model Showing the Flip Cap Dust Tolerant Housing opened prior to mating.

The seal on the red housing (center) is shown that will seal the housings, and the seal on the open grey cap (bottom left). The cam surface is shown in the gold insert (center), the shape memory alloy hinge (upper center), and the tri-action levers can be seen on each handle.

The dust-tolerant intelligent electrical connection system has several novel concepts and unique features. It houses a COTS electrical/fluid connector in a dust-tolerant housing, provides the operator with a cam type lever system that reduces forces required to open the protective caps, and a second cam inside the housing that provides the mechanical advantage required to slide the pins into the sockets for electrical connectors or depresses the poppets for fluid connectors easily, closes the caps autonomously if dropped preventing dust from accessing the connector, protects the connectors and the inside of the caps from dust intrusion. A patent application was filed on March 12, 2014 and is now pending.

### **DUST TOLERANT AUTOMATED UMBILICAL**

The Dust Tolerant Automated Umbilical (DTAU) is an umbilical system that is designed to be installed on space vehicles that land on an extraterrestrial body. The umbilical system includes two halves of an umbilical designed to mate together autonomously to transfer gas and/or fluid commodities and electrical signals between two surface vehicles or entities. One half of the system is the Active Umbilical, containing a deployable arm, an alignment system, and the active umbilical box. The other half is the Passive Umbilical, consisting of the passive umbilical box. The Active Umbilical system is to be bolted to the lander deck where it is stowed during transit flight and landing. The Passive Umbilical is attached to a movable entity (a rover or pallet). The Active Umbilical is deployed from the deck to a position just above the ground surface. The other vehicle is then moved to the lander so that the two umbilical boxes are in close proximity. The Active Umbilical then is commanded to align itself and mate to the Passive Umbilical. After a successful mate, commodities and electrons can be transferred. When desired, the umbilicals are commanded to de-mate. This process can be repeated as required.

The DTAU was designed at the Kennedy Space Center by a team consisting of NASA Engineering (NE) and Team Engineering Support Contract (ESC) Engineering personnel in support of the Surface Systems Development project and was funded by the Advanced Exploration Systems (AES) project and the 21st Century Launch Complex program.

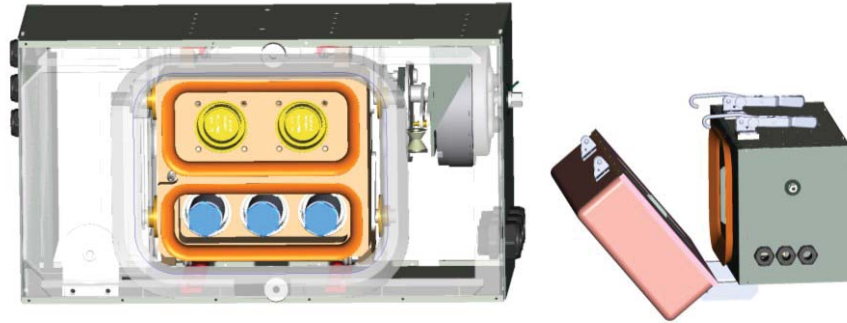


Figure 4. Model concept showing the DTAU with dust protective doors in the open position (Left). The upper row has one each 8 conductor electrical connector, and one each 128 conductor data connector. The bottom row has 2 each 1/4" fluid connectors, and 1 each 1/2" fluid connector.

While the DTAU was designed for use on a space craft lander and pallet or rover vehicle, the system could also be adapted to other uses and situations. The umbilical plate inside the umbilical box on the Active Umbilical Assembly contains three fluid/gas connectors (QDs) and two electrical connectors. These are the umbilical connectors that will be mated to the Passive Umbilical plate for transfer of commodities and electronic signals. The Active Umbilical Assembly includes the lines and harnesses that are attached to these connectors. These lines are routed from the back of the umbilical box, are clamped/tied off along the arm, then exit at the base of the arm. These lines each have QDs/connectors on their ends.

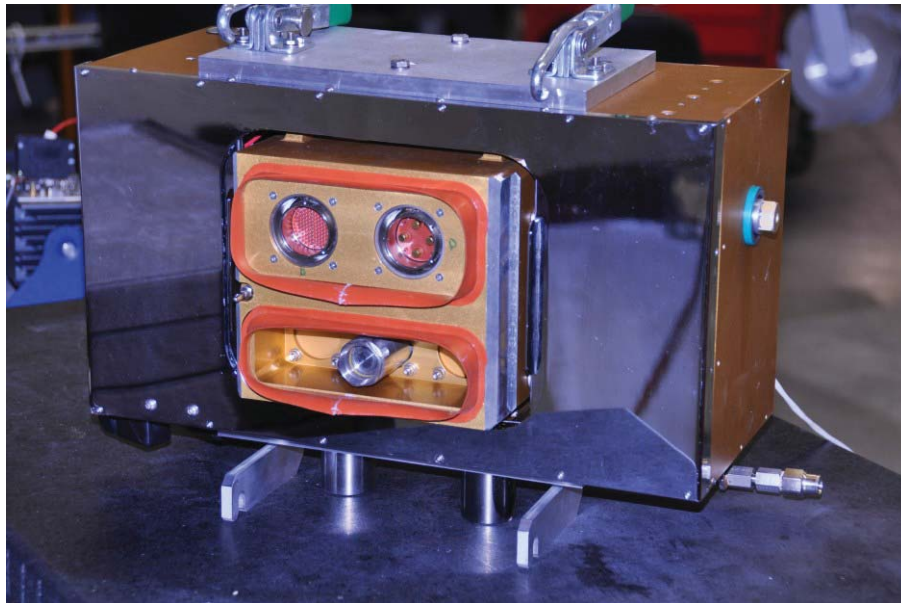


Figure 5: As Built Prototype of the DTAU – Showing the Active Half with One Data, one Power and one Fluid Connector Only Installed.



Figure 6: Close-up Views of the “as built” Prototype of the DTAU – Showing the Active Half (left) and the Passive Half (right)

### **PLANETARY SURFACE ACTIVITIES USING DUST TOLERANT UMBILICALS AND CONNECTORS**

Typical applications for the DTAU include:

- In-Situ Resources Utilization (ISRU) commodities transfer
- Planetary ascent vehicle propellant loading and conditioning
- Planetary surface hopper vehicle propellant loading and servicing
- EVA O<sub>2</sub> breathing air replenishment
- Habitat consumables and multiple element habitation complexes
- Fuel cell consumables replenishment
- Modularity of surface systems elements
- Pressurized Surface Rover docking to another rover or a habitat
- Payloads interfaces for the Pressurized Surface Rover
- Surface assembly and integration of multiple elements

A variety of applications are listed above, which shows the importance of this modular device for solving interface needs in a versatile manner. The DTAU is capable of being assembled into many different systems and provides a standard interface that reduces the parts count, lowers costs and creates a better logistics situation for any required repair and replacement of parts, through commonality.

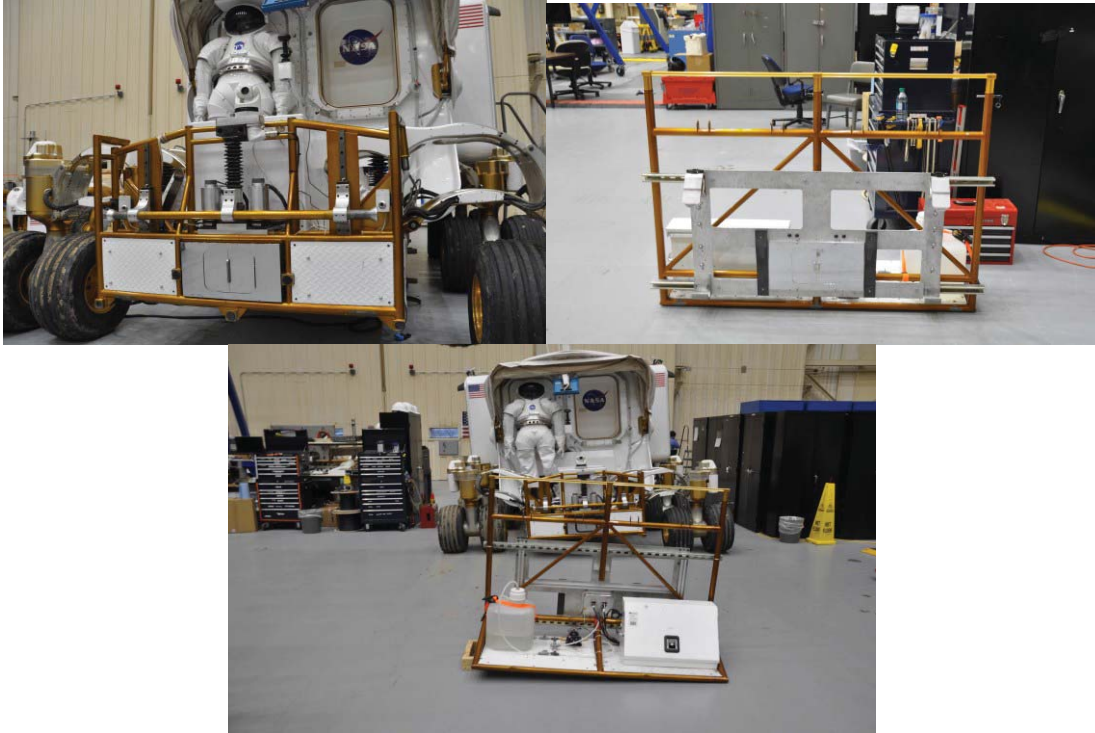


Figure 7. Showing the DTAU Mounted to the Front of the Space Exploration Vehicle (SEV) Quick Attach (QA) Mechanism (upper left). The DTAU Passive Side (upper right with doors closed) Mounted to the QA Portable Utility Pallet (PUP) implement, and the SEV Approaching the PUP to Attach the PUP and Mate the DTAU Active Side to the DTAU Passive Side.

### **ISRU SYSTEMS “END TO END” TEST**

Ongoing work in this area performed at the KSC Swamp Works laboratory has resulted in fabricating a mock-up Lander structure, a passive and active umbilical, and a working prototype of the Flip Cap Dust Tolerant Connector Housing. This hardware may be integrated to create an end to end mission demonstration that would test the interface capabilities of the technologies as one system.



Figure 8. Showing the 2010 “Dust to Thrust” Field Demo on Mauna Kea, Hawaii



In the above photo, the excavator (left) is delivering regolith to the hydrogen reduction reactor (center). The hydrogen reduction reactor heats the regolith to near melting temperatures then uses dry hydrogen gas to pull out oxygen molecules making water vapor. The water vapor is then cooled and sent to the electrolysis system (right) where the water is separated into hydrogen and oxygen gas then liquefied and stored for thruster firing operations. The umbilicals and connectors prototyped by NASA and discussed in this paper will be used for each connector/umbilical interface during the next ISRU field demonstration.

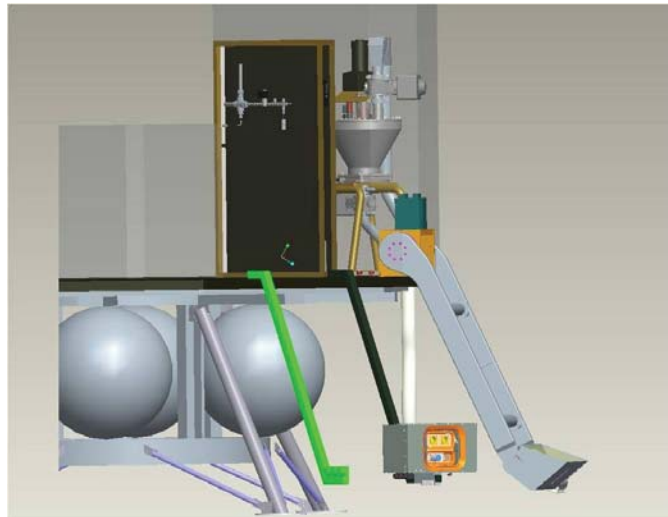


Figure 9. Showing the DTAU (center umbilical) mounted onto a Lander deck arm with its doors in the open position.

The Flip Cap Dust Tolerant Housing may be used during planetary body Extra Vehicular Activities (EVA) to make fluid, power, and data connections without requiring a clean room as is currently the connector mate/de-mate Concept of Operations (Con-Ops)

## **GOALS**

NASA is on a quest to find/design a connector housing that does not expose the connectors to the environment at all. This would be a design that could be mated while under water without getting the connectors wet or in space without ever exposing the connectors to dust. NASA KSC has developed many different dust tolerant concepts and aims to continue researching concepts and offer customers choices for connector and umbilical dust mitigation hardware.

One approach to meet this goal, may be using a self-healing membrane as a dust barrier for electrical connectors, while also combining lotus leaf technology for applications where a dust-resistant coating providing low surface tension is needed to mitigate Van der Waals forces, thereby disallowing dust particle adhesion to connector surfaces. Another approach would be to use a ruggedized iris mechanism with an embedded Electrodynamic dust shield as a dust barrier for electrical connectors where required.

## **CONCLUSION**

NASA Kennedy Space Center has researched and made prototypes of a dust tolerant protective connector housing and dust tolerant multi-function umbilicals for use on terrestrial, and extraterrestrial bodies such as the moon, mars, and asteroids that will provide dust mitigation for connector and umbilical couplings over a wide range of data, power, and commodity transfers. Testing has shown significant improvement in dust mitigation for the connector housings and umbilicals tested.

NASA KSC would like to continue this technology development and are seeking NASA and external partners that may have funding and a need for this technology. The future project would continue design evolution, prototypes and testing of an advanced dust tolerant connector housing, and an advanced dust tolerant umbilical.

## **ACKNOWLEDGMENTS**

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