Proposal for 'RETURN TO THE MOON' ASEG Challenge

Title: 'Full Polymer Jacket' – Space Suit Protective Wear to Prevent Regolith Contamination

'All innovations come with new technical considerations.'

Executive Summary:

An all-in-one (full body) space suit cover ('Full Polymer Jacket', FPJ) – customized for each Lunar team member -- and made from recyclable polymer or co-polymer material (with chemical characteristics appropriate and necessary for most lunar surface/sub-surface activities) is described and illustrated. An accompanying photo-diagram is provided. Additional technical information is provided covering: 'suit-up' and 'suit-off' ('jacketing', de-jacketing') protocols, jacket fabrication (e.g., additive, 3D-printing/rapid-prototyping, etc.) considerations and requirements, possible polymer (jacket) materials and refinements/augmentations, and any potential lunar habitat infrastructure modifications needed for jacket use integration.

The Problem:

The challenge of dealing with small lunar regolith particles ('Moon dust' or lunar dust) – especially those of micron or nanometer scale -- which can contaminate space suits, auxiliary equipment, lunar habitat, and the physical bodies (via inhalation) of lunar inhabitants, and requiring nearly constant safe-guarding against (i.e., removal, cleaning, repairing [if damage occurs], and maintenance of suits, equipment, habitat, etc.) is well-known to NASA/ASEG.

Innovation (and Integration):

The proposed jacket(s) are intended to be worn whenever lunar base inhabitants exit the base for any exterior mission(s). These are full-suit coverings and are customized (according to full-suited size measurements) for each inhabitant. Though customized, each suit is 'loose fit' (i.e., an all-around gap exists between jacket and suit) to accommodate a full range of motion (stretching, bending, lifting, reaching, etc.). The material should be relatively soft/flexible (with *as needed* 'formability'), non-conductive (with a low 'friction coefficient), and fully recyclable. There are four key features to each jacket [see also: accompanying diagram, next page]:

- Jacketed (finger-separated) glove coverings (for full digit usage)
- An acrylic (or comparable polymer) panel (as a jacket 'insert') over the helmet visor for 'clearer than glass' (unobstructed) visibility
- Reinforced (multi-layer) boot jacket soles (for durability over lunar terrain)

- Front-centered jacket seam for ease of jacketing and de-jacketing (seam is heat-/adhesive-sealed during jacketing, and, split or broken prior to de-jacketing)

[see: **References**, **pg. 4** - photo-diagram of the FPJ with key features indicated/described]

Regarding the four key features:

1] The glove (finger-separated) jackets may be fabricated/3D-printed separately (but with the same polymer stock, possibly double-layered for extra durability) and then attached after the main jacket 'body' is fabricated. However, ideally, the glove jacket extensions would be fully integrated with the jacket fabrication process (i.e., a 'one-step' fabrication). **2**] The helmet visor panel (made of flexible acrylic polymer) will need to be 'inserted'/applied after jacket body fabrication (and applied/sealed over a jacket face 'cut-out'). The 'visor panel' should allow the same full range of viewing as the helmet visor. **3**] The boot jacket soles would likely need multi-layer reinforcement to withstand regular contact with rugged/irregular lunar surfaces. These jacket soles may require separate fabrication and application (as noted above) but possibly could be integrated with the jacket body fabrication process ('one-step', etc.). **4**] The front-centered jacket seam is crucial for ease of jacketing/de-jacketing and would require a sealing procedure (e.g., applying a 'heat gun', adhesive, or self-adhering silicone strip) for FPJ seam sealing/closure.

Jacketing and de-jacketing protocols would need to be followed; the jacket would be laid flat ('pancaked') with the leg and boot coverings accessible for 'step-in' jacketing (with the rest of the jacket pulled up and over the Life Support System/LSS 'backpack', helmet, etc., followed by insertion of the arms into the jacket sleeves, etc.). This jacketing protocol would require assistance from a second person (i.e., following suit-up inside the habitat). The final step would be the sealing of the jacket seam. De-jacketing could be accomplished solo inside the airlock compartment, or, inside a low-pressure, airlock antechamber to reduce 'air-born' particles and the possibility of 'carry on' dust entering the air-lock/habitat (if no 'dust evacuation' mechanism is present in airlock compartment). It is possible that the removed jacket could be reused if a thorough de-dusting procedure is developed but most likely the jacket will need to be recycled (with a *prior* inertial and/or magnetic separation step) after each use.

Next Steps:

Polymer/co-polymer chemistry (formulation/synthesis) is quite advanced (high TRL) and new polymers (and co-polymers) and polymer synthesis techniques/technologies are undergoing regular discoveries, innovations, and break-throughs. Consequently, the requirement that the proposed FPJ be fully recyclable should be both doable and mandatory given the diverse options for appropriate 3D-printable polymer 'feed stock' (e.g., thermoplastic elastomers, TPEs), and, is in keeping with a sustainable presence on the Moon or a future mission to Mars [see:

References, pg. 5 - this solver's previous winning proposal for **NASA's (2022) Waste 2 Base – Materials Challenge: 'Make-Break-Make (Again)**']. Many new polymer characteristics can be 'fine-tuned' with specific qualities (e.g., non-conductivity, low friction co-efficient, high-formability, etc.) – in addition to 'closed-loop' recyclability – and, increasingly, thermoplastic copolymers (dual combos of polyolefins, such as PU, PP, PE [HDPE/LDPE, FTPE], possibly with PEEK as a radio-protective additive). Also: functional self-healing 'smart polymers' or polymers with nano-structured topologies that prevent dust adherence should be investigated (if integrable with a lunar additive/3D-printing apparatus). Research to identify and test optimal FPJ polymeric material(s) for the FPJ will be required.

As for 3D-printing (aka additive printing, rapid-prototyping, etc.) of the FPJ: promising contemporary fashion design technology (moderately high TRL) such as the 'Electroloom' ([see**: References, pg. 5, Note**]; see also: 3DPI.tv) and processes like *Fused Deposition Modeling* (e.g., the Delta WASP 3MT FDP for additive printing [see additional links: **References, pg. 5, 6**]) – or refinements/improvements of these – can/should be integrated with the Lunar base's 3D manufacturing apparatus. But, if the 'suitability' or capability of *in situ* 3D-printing the FPJ is not doable, then fabrication of the FPJs can be achieved on Earth and the customized FPJs (*in multiple*) can be transported into space along with the Artemis mission team.

As for any infrastructural modifications: Depending on regolith carry-on risk (via a pre-habitat-entry airlock compartment), it may be necessary to construct an *antechamber* (to the airlock compartment) with very low pressurization (and possibly a built-in floor suction/evacuation mechanism) to 'hold down' (and/or evacuate) any random dust particles that may be shed from the FPJ. In that regard also, developing and practicing the (TBD) de-jacketing protocol will be important for the twin goals of a dust-free space suit and habitat.

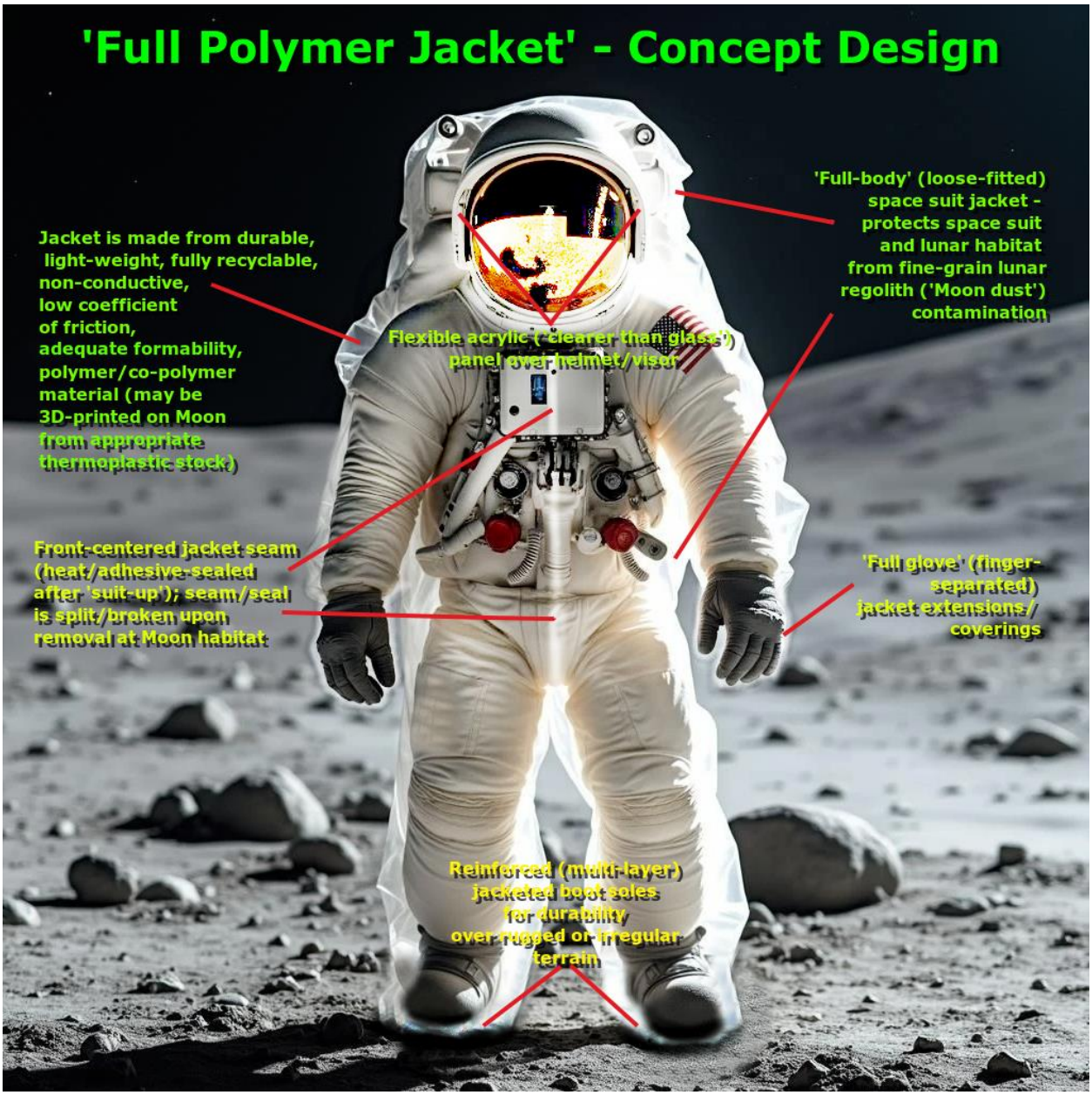
Finally, regarding the TRL of the proposed FPJ: the TRL level of 4 was selected insofar as the actual designed and fabricated FPJ has not been accomplished yet, nor, of course, tested (in laboratory or 'relevant environment' on Earth). However, the supporting technologies such as polymer chemistry/synthesis, and, 3D-printing/rapid prototyping (for thermoplastic elastomeric/polymeric components and even fabric/clothing design) are both at relatively high TRLs (6 - 7 or higher) and are buttressed by ongoing innovation [see: **References, pgs. 5, 6**]).

Concluding Statement:

A full-body protective (sealed) covering for a space suit (a 'suit for the suit', if you will) may seem obvious. However, I have not seen any design(s) for such 'protective wear' for this specialized purpose (though this sphere of innovation is vast). Regardless, the proposed FPJ concept would seem to be a highly practical and achievable solution to the problem of regolith contamination. -- M.R.

REFERENCES:

Full Polymer Jacket - Photo-image Diagram



Example images of (nearly) full-body jackets ('hazmat' suits) with backpack coverings:

Polymer Chemistry / Synthesis (for 'closed-loop' chemical recycling):

(NASA 'Waste 2 Base – Materials Challenge, 2022) **'Make – Break – Make (Again)'** - A Closed-loop Chemical Recycling to Monomers schematic and proposal: **https://www.herox.com/WasteToBase/round/2126/entry/39658**

Research paper (polyolefin recyclability)**:**

Polyolefins in the Circular Economy: Advances and Recyclability **https://www.thieme-connect.com/products/ejournals/pdf/10.1055/a-2554-7254.pdf**

3D-Printing / Additive Printing / Rapid Prototyping (notes, articles [contemporary fashion design], on-line channel, industry websites):

- 'Electroloom' (3D printing for clothing/fabric) – **Note**: under-developed technology (start-up) closed down in 2025 due to insufficient funding and R & D refinement - news link: https://3dprintingindustry.com/news/electroloom-closes-down-93777/

- 3D-Printing channel: 3DPI.tv: https://www.youtube.com/3DPITV

- 3D-printed clothing: 'best fashion material' according to fashion designer Chiara Giusti: Laripur TPU [granular thermoplastic polyurethane; see; COIM Group] – recyclable, transparent, smooth, multi-color – TECHNĒ Clothing line – utilizes **Fused Deposition Modeling (FDP)** via Superforma's Delta WASP 3MT FDP for Additive Printing [see: related link, below, pg. 6]

Reference article:

'Italian Fashion designer uses FDM to create 3D printing clothing line TECHNĒ - 3D

Quote: “The combination of polymeric structures and fabric takes the best of both materials, allowing customization and the experimentation of new textures while ensuring comfort.” Giusti said, “3D printing on tension-activated textiles does not just mean using textiles as a substrate: 2D geometries are printed on fabrics in tension on the printing plate and, when released, the textiles achieve complex 3D volumes. This means that this specific technique guarantees wearability, soft-touch, breathability, and, most importantly, structure.”

Related Link: (Superforma’s) **Delta WASP 3MT FDP** for additive printing: https://www.3dwasp.com/en/wasp-3mt-hdp-big-3d-printer/

- Relevant 3D-Printing links (labs, groups, manufacturers):
    - **COIM** (international polymeric materials production): https://www.us.coimgroup.com/
    - **ProtoLabs** (rapid prototyping lab): https://protolabs.com/en-gb/
    - **Colibrium** (GE aerospace company): https://www.colibriumadditive.com/
    - **STRATOSYS** (3D Printer manufacturer): https://www.stratasys.com

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Edited List of this Solver’s Awarded Open Innovation Challenge Proposals/Solutions (M. Ricciardi, 2012 - 2024)

Winning solutions/proposals:

[1] Challenge: (NASA) Beyond Boundaries - NASA's New Technology Search

Proposal: **'Polymer/Co-Polymer Nano-Composites for Shielding from Space Radiation'**

OI platform: Freelancer.com

Date: October, 2023

[2] Challenge: (NASA Tournament Lab) Waste to Base Materials Challenge: Sustainable Reprocessing in Space

URL: https://www.herox.com/WasteToBase/updates

Proposal: ('Trash' category**) 'Make - Break - Make (Again) - A Closed-Loop CRM (Chemical Recycling to Monomers) Model-Schematic**'

OI Platform: HeroX

Date: April, 2022

[3] Challenge: (Coinbase Giving Award) Blockchain Breakthroughs for a Better World

URL: [https://www.herox.com/BlockchainBreakthroughs/teams]

Proposal: 'Securing the Vote with Blockchain'

OI Platform: HeroX ('Most Original')

Date: March, 2022

[4] Challenge: (Tom Riley, retired NASA engineer, author) Alternative to Fear (Stimulating Collective Climate Action 'Buy In')

Proposal: 'Stimulating Generative Motivation for Collective Climate Action 'Buy-In'

& Achieving the Next Big Social Project'

OI Platform: HeroX (1st Place, one of two challenge awards)

Date: July, 2019

[5] Challenge: (WHO/GPEI) Polio Eradication: Addressing Anti-Vaccination Propaganda on Social Media

Proposal (title): 'Implementation of 3 Key IDEAS for Detection, Control, and Response to

Anti-Vaccination Propaganda in Pakistan (& Building A Dynamic DCR System)'

OI Platform: InnoCentive.com

Date: 8/11/2019

[6] Challenge: (U.S. Dept. of State) 2013 Innovation in Arms Control Challenge: What Information Technology Tools and Concepts Can Support Future Arms Control Inspections?

URL: https://2009-2017.state.gov/t/avc/innovationcompetition/index.htm

Proposal: 'Using VLC (Visible Light Communication) to Support & Expedite Arms Control Inspection'

OI Platform: InnoCentive.com

Date: May, 2014

[7] Challenge: (Ford Motorcar Co.) Service Accessory for the Ford Van Series (public service: Johannesburg, S. Africa)

Proposal: 'Service Accessory for the Ford Van Series - A Mobile Public Service Micro-Cinema'

OI Platform: InnoCentive.com

Date: 11/16/2014

[8] (USAID, NIH, CDC, DOD) Fighting Ebola - A Grand Challenge for Development

Proposal: 'Using Socio-Metric (SM) Badges to Monitor Potential Exposure and Expedite Contact Tracing Amongst Healthcare Providers'

URL: [No longer available; news article: https://fedscoop.com/usaids-ebola-grand-challenge-gives-world-hand-innovation/]

OI platform: OpenIDEO.com [Note: one of 28 winning proposals out of 600+ entries]

Date: Nov., 2014

[9] Challenge: (Pharmaceutical Industry/NDA) What Disruptive Innovations Does Pharma Need To Discover Tomorrow's Drugs?

Proposal: 'Towards a Combined / Integrated Approach to Drug Discovery'

OI Platform: InnoCentive.com

Date: May, 2012

[10] Challenge: (Anonymous; possibly IC Contractor) Strategy to Assimilate Unstructured Information

Proposal: 'A Model for Assimilating Unstructured Information'

OI Platform: InnoCentive.com

Date: February, 2012

[11] Challenge: Challenge: (NIKON) How to Augment a Camera to Capture More than a Snapshot

Proposal: 'Concept for an Augmented Camera - My Photo Story Poem'

OI Platform: InnoCentive.com

Date: January, 2012

<u>Honorable Mentions</u> (usually non-monetary, with exceptions):

[12] Challenge: (Amentum Space Exploration Division [formerly JSEG]) Lunar Life

Proposal: 'A 2-Stage Lunar De-Dusting System'

OI Platform: HeroX

Date: March, 2023

[13] Challenge: Light Up Your Ride (HELLA)

Proposal: 'UV light enhancement for seeing in low-visibility'

OI Platform: HeroX

Date: January, 2023

[14] Challenge: (USAID & Humanity United) How to Identify and Spotlight Intentional and Unintentional Enablers of Mass Atrocities?

Proposal: 'Revealing the Ecosystem of Violence'

OI Platform: InnoCentive.com

Date: 2012

Finalist / Semi-Finalist (or Short-listed) Proposals/Solutions [non-awarded]:

[15] Challenge: (Amentum Space Exploration Division [formerly JSEG]) Lunar Life Odyssey

Proposal (Power Point): 'In Situ Production of LN2 (Liquid Nitrogen) for Lunar Dust Mitigation'

OI Platform: HeroX.com (top eight finalist)

Date: October, 2023

[16] Challenge: It Doesn't Take a Brain Surgeon (HORAO)

Proposal: 'EVM as an AR Overlay for a Surgical Microscope' (re: detecting eary stage gliomas)

URL: https://www.herox.com/HORAO/update/2611

OI Platform: HeroX (note: one of 13 semi-finalists out of 45 submissions)

Date: 2018

[17] Challenge: The PILOT (NAB) Innovation Challenge (2016/17)

Proposal: 'RESILIENCE- Preparing for Climate Change' (finalist, 1 of 12)

> Summary: The RESILIENCE project will situate the local news station as the central hub (and "integrator") of climate change resilience information, resources, and services and thus make each station integral and indispensable to its community in the coming decades of real and

increasing climate change impacts to the local community. URL: https://nabpilot.org/pilot-innovation-challenge-announces-12-finalists/

OI Platform: NAB / https://nabpilot.org

[18] Challenge: (Governments of Spain, Basque Territory) DISONANCIAS – Catalonia (artist-industry partnership program; now called *Interconnexiones*)

Proposal: 'A Knowledge Acquisition Environment (System) for Long-Term Space Habitation' (1 of 2 finalists; Greek-French team won the challenge)

Date: Fall, 2009

[19] Challenge: (The Economist Magazine) Envisioning the 21st Century Cyber-School

Proposal: 'Envisioning & Designing the 21st Century Cyber-School' (Note: placed in top ten out of 120 submissions)

Date: June, 2008

[20] Challenge: (The Rockefeller Foundation) Reducing the Risk of Malaria with Solar Powered Device

Proposal: 'LTP (Lure, Trap, Poison) - ANTI-MALARIA (SOLAR POWERED) DEVICE'

OI Platform: InnoCentive.com [note: 1 of 5 top-rated designs/proposals]

Date: 2008

[21] (TSA) Passenger Screening for infectious Agents

Proposal: 'Ocular Fluid (Vitreous Gel) Density as Gauge/Indicator of Influenza Exposure & Ocular Laser Sensing System for Influenza Indicators (OLSSII)

OI Platform: InnoCentive.com [note: 1 of 5 'top-rated proposals']

Date: June, 2009

[22] (Swiss Surgical group) It Doesn't Take a Brain Surgeon! ('HORAO' Challenge)

Proposal: (Detecting gliomas in brain tissue) 'EVM as an AR Overlay for a Surgical Microscope'

OI Platform: HeroX (note: one of 13 semi-finalists out of 45 submitting)

Date: August, 2019

[23] Challenge: (USAID/Humanity United Tech Challenge) Alert

Proposal: 'Knowing by Numbers' (top ten finalist)

OI Platform: OpenIDEO

Date: Feb., 2013

ADDITIONAL AWARDS & INNOVATION/DESIGN WORK:

[24] Designer/creator of original live-action (micro-gravity) space game 'Zero-Gordian' (Dec. 2016) and submitted to the Space Games Federation #EqualSpace challenge/competition URL:

www.spacegamesfederation.com

Awards: 'Finalist' (October, 2019); Winning game concept: July 1, 2022 (1 of 5 winners of the inaugural space games competition)

[25] The Longevity Prize 'quick pitch' Challenge (XPrize Community Design Forum)

Proposal: 'What we talk about when we talk about Aging'

Award: Winning submission/application; invitation to the 2019 'Visioneers' Conference

Date: October, 2019