

# Risk Assessment of ISRU in Lunar Base Missions Scenarios



## Risk of ISRU-Human Involvement

### How is ISRU going to Reduce Risk in Missions?

- Enable local self-sufficiency
- Provide life support supplies
- Provide propellants
- Power
- Provide infrastructure for safe-living environments
- Supports Utilization of robust Robotics and Automation
  - Lunar rover vehicle damage
  - Equipment failure/breakage
  - Astronaut accidents
  - Containment boxes seal failure
  - Time loss/Time impingement

		Scenario Criticality Ranking of CET						
		Observatory	Science	Settlement	Gateway	SRU	Tourism	Overall Avg.
1	Radiation Shielding	1	1	5	2	4	2	2.5
2	Earth Entry Vehicle	6	2	3	3	7	1	3.7
3	Lunar Transfer/Excursion	2	3	13	4	5	3	5.0
4	Solar, Photovoltaic	4	4	7	1	14	5	5.8
5	ISRU Shielding	10	6	1	8	6	7	6.3
6	Closed Loop LSS	17	13	2	5	9	6	8.7
7	Automation/Robotics	3	9	11	6	8	17	9.0
8	Hard Module	7	5	10	11	17	4	9.0
9	ISRU Life Support	18	15	4	7	3	8	9.2
10	ISRU construction equip.	14	17	6	10	1	15	10.5
11	Fuel Cell	9	7	19	9	12	10	11.0
12	Direct One-Way (cargo)	11	8	9	12	13	19	12.0
13	Direct Lunar Landing	5	10	14	17	16	12	12.3
14	Heavy Lift (STS derived)	8	11	16	14	15	13	12.8
15	ISRU Transportation	22	25	8	13	2	9	13.2
16	ISRU Structures	20	21	12	15	11	16	15.8
17	Partially Closed LSS	12	12	18	19	23	11	15.8
18	ISRU Power	19	26	15	18	10	14	17.0
19	Underground Dwelling	13	19	17	20	19	20	18.0
20	Solar, Thermal	16	18	20	21	20	23	19.7
21	Physical/Chemical	25	20	22	16	22	18	20.5
22	Nuclear Static	15	16	23	23	21	25	20.5
23	Nuclear Dynamic	27	22	21	22	18	21	21.8
24	Open Loop LSS	21	14	25	25	27	22	22.3
25	Heavy Lift (Sat V)	26	24	24	24	25	26	24.8
26	Solar Dynamic	23	23	27	26	26	27	25.3
27	Inflatable	24	27	26	27	24	24	25.3

# ISRU Technologies Considered Most Critical

Rank	Order	SRU	Criticality Mean Value
	1	ISRU construction equip.	4.00
	2	ISRU Transportation	3.93
	3	ISRU Life Support	3.93
	4	Radiation Shielding	3.90
	5	Lunar Transfer/Excursion	3.90
	6	ISRU Shielding	3.82
	7	Earth Entry Vehicle	3.79
	8	Automation/Robotics	3.75
	9	Closed Loop LSS	3.75
	10	ISRU Power	3.75
	11	ISRU Structures	3.72
	12	Fuel Cell	3.68
	13	Direct One-Way (cargo)	3.64
	14	Solar, Photovoltaic	3.59
	15	Heavy Lift (STS derived)	3.52
	16	Direct Lunar Landing	3.50
	17	Hard Module	3.45
	18	Nuclear Dynamic	3.43
	19	Underground Dwelling	3.36
	20	Solar, Thermal	3.33
	21	Nuclear Static	3.29
	22	Physical/Chemical	3.27
	23	Partially Closed LSS	3.25
	24	Inflatable	3.11
	25	Heavy Lift (Sat V)	3.07
	26	Solar Dynamic	3.07
	27	Open Loop LSS	2.86
		M E A N A V E R A G E	3.71
		Selected Mean Average	3.72

# Expedition Risks

Launch risks/In-Space Risks/On-Site Risks

Cost and Schedule

Funding / Investment Opportunities

Saving the Earth/Human Species

Integration/Systems Engineering

Use of resources / identifying new resources

Trade routes; ability to go to Mars and Beyond

National prestige; leadership/greatness

Science enabling and enabled by exploration

Technological Advancements

Satisfy a need for achievement- 'climbed it because it was there'.

Need to do something special-our predecessors lead the way,  
let's take it to the next level, for the next generation.

Satisfy Curiosity

“The greatest risk, I believe, at this juncture in our quest, is identifying what is at the poles; if there is actually lunar-ice.” Harrison Schmitt, August 2005.

The most important thing that needs to be done, is the identification of what the resources actually are, before we do anything else, we need to identify what it is; then we can solve the other factors of processing it.

Ken Johnson, JPL @ Bernie's fish fry last night.

# Most Pervasive Issues of ISRU systems

- **Clearly Defined Architecture**...know what we are doing
- So we'll know if it [ISRU] is what we really need
- Identifying what the resources are
- Be Prepared for Unexpected Unknowns and Deal with it
- Energy consumption...how much power do I need, trade offs, what kind of systems to use...
- Equipment Mass and Size
- Automation and Tele-operations
- Ease of Operation, complexity
- Ease of Assembly
- Maintenance and Durability
- Consumable Re-supply
- Compatibility with
  - Lunar Environment
  - Lunar Base Systems and Activities

But what are the *REAL Risks*?

## Risk of Not Having a Well-Defined Plan

**Steve Squyers, Cornell University, MER, “Roving Mars”**

“You look at Apollo, you look at Gemini, and you look at Mercury, you look at what they accomplished in those days, and it [NASA] was a huge organization. It was in some ways bigger than NASA of today. Yet, they got things done.

When I look at that, what strikes me is that there was a common thread through those organizations, and that is **they knew exactly what it was that they were trying to do...If you have a common goal that is clearly understood by everyone** in your organization, I don't think it matters how big your organization is.

## Unknown or Intangible Risks

Writer/Climber Perspective session; Risk and Exploration.

**Bill Stone**, Engineer/Deep Cave Explorer President;” Stone Aerospace “Hydrobot-Europa DEPTHX

**“You can control risks. There’s one thing you can’t control, but you can prepare for, and that’s the weather [or solar activity, etc.]....NASA is a technological gem on this planet. But, unfortunately, you don’t have any true ‘expedicionarios’ here, as we say down in Mexico-true expeditionary people who think, ‘Two years from now we’re going to run an expedition to the Moon.’ And then go do it. The way NASA thinks these days is, ‘We can develop these technologies and, maybe, 15 to 20 years from now we’ll be back on the Moon.’ ‘That’s too late.’”**

**Why is it that it’ll take that long?** Financial constraints for whatever reasons...

## Risk Mitigation

**“Luck is not a factor, Hope is not a strategy, Fear is not an option,” James Cameron Writer/Director & Undersea Explorer.**

**“To succeed in any complex task... You need to make your own luck by rigorous application of a robust process. You test everything in a very disciplined fashion, you don’t guess, you know the answer, you anticipate every negative condition that might possibly prevail...to respect [your] adversary-not the ocean, but the adversary: entropy, which as you know, is the tendency of things to go from a state of organization to a state of chaos.”**

## **Risk Adverse vs. Risk Acceptance**

**Our predecessors did it at the *Same Time they were Doing the Job of Getting Us There.* (e.g., one-up testing or in '68 when the Russians were arguing over whether to send humans versus animals in the Zond 5 and 6, meanwhile the US sent Apollo 8 and beat 'em.)**

**Why do we worry so much about seat belts and bicycle helmets and whatnot...sure they are great at saving lives, but we still rode our bikes and drove our cars and put them in when we recognized we liked having them, we didn't stop riding and driving, but just added them in while we were doing it.**

**Why is it that a few bad accidents by a small portion of the whole, cost the whole so much in insurance?**

**Because the accidents cost, the whole, so much?**

# Critical Risk Identification

**“What is the most critical risk?”...Launch? Human factors?**

**The Most Critical Risk is:**

**Program Risk; losing the program; program termination, losing the contract.”**

**Brad Blair** Oct. 2005, Moon Base Conference, Washington DC.

**How do we lose programs?...**

- insufficient financial resources, lack of honoring commitments/promises
- lack of support public/bureaucratic/congressional/presidential/financial
- bad engineering/bad science
- poor preparedness
- lack of contingency planning
- ignorant or stupid management practices
- Lack of insight or historical knowledge

**How do we rectify that?**

**•6 P's Proper Preparation Prevents Piss Poor Performance  
(Roy Christenson)**

But, as **Ed McCullough** would say...**“Avoid Analysis Paralysis”**

**Biggest Risk is Not Doing Anything**  
**or Doing Things that are *really* Not Doing Anything except**  
**collecting a paycheck.**

We've talked so much about the risk of exploration, but nothing about the risk of not exploring. **Is there greater risk of not exploring than exploring?"** Gordon Osinski, University of Arizona

Mike Griffin stated, "President Bush stated that 'exploration is written on the human heart', it is embedded in our DNA; descendants of beings migrated to someplace else. For our species' successful strategy, expansion of habitat is a good thing. Those that chose not to; did not survive."

Individuals and species act in the large societies and cultures do well; nations have prospered, those that took the effort to explore left their footprint on the world. Languages over the globe are indicative of that.

## Risk of NOT Exploring

**John Chatterton, “Exploration is who we are. We should continue on the path of exploration or quit.”**

**Sylvia Earle, “Something is going to happen to us as a species...we have to explore...all these other systems that are at risk right now...We have the capacity to turn things around. The real question is, are we going to use our knowledge in the spirit of exploration to do it? I mean, Goethe said, ‘It’s not enough just to know, You must act.’ Well, we know. Do we have the capacity, now, to act?”**

**I believe we are in the process, of actually doing it, and we have been given an opportunity to not only do it, but to define it, control it, and reap the benefits of it.**

## Government Driven vs. Entrepreneurial Driven

**“As we step up our activities on the Space frontier, many companies, universities, and individual citizens will become increasingly dependent on the political whims and necessities of the Federal government.**

**And if that drift continues without check, the United States may find itself becoming the very kind of society that it is struggling against—a regimented society whose people and institutions are dominated by a central government...**

**The competitive system...rewards the creative and the efficient...It provides an incentive for risk not only on the obvious ideas, but also on the ‘long shots’. It provides a natural and effective system for the elimination of failure, complacency, and delay”**

**Ralph J. Cordiner**, Chairman of the Board, General Electric Co.  
1961, Certificate of Appreciation from the DoD 1958

# Risk of Not Communicating our Work, Inspirations, Incentives, Objectives, Passion, Concerns To the General Public or Investors

**Andy Presby**, Student Naval Postgraduate School, Monterey, CA.

**Why do we explore?** Not all of us do for the same reason... looking at NASA from the outside in...**the public is not concerned about risk maybe as the explorers are**...[they] seem to have **sort of understood** that you guys **accept the risk** and do it because you love it [exploration], for whatever reasons...**What the public is worried about is, WHY are we going?** What you need to walk out of here with is an intensified outreach program to explain to the public, in terms they can understand clearly, **Why they should pay for what we all agree is one of the most important things our government does for us in this country.**”

**The General Public needs to see the comparative analysis of what are our plans, *definitively*, compare the arguments, and what are the benefits...clearly defined so a decision to support the Vision can be done with minimal hesitation.**

## Summary

The risks we take by creating the advancements in technologies [ISRU] by going to and learning how to permanently live on the Moon will enable us in our understanding and developing ways and means to exist in an ever increasingly changing environment here on Earth (i.e., global warming, pollution, acid rain, energy systems, etc.) and ultimately provide for the capability to reverse the detrimental impact we have on our Earth by being able to directly observe and study the Earth, and the Earth-Moon System, from the Moon and use that information to help ourselves and Mother Earth.

Not only that, but we have proven as a nation, and more importantly as humankind, it is possible to go to the Moon, accomplish science, exploration, and get back alive and well. The Vision can be accomplished with the support and wherewithal we, as a nation and/or peoples of the world, are capable of; the question then arises as to what we wish to support and then set ourselves to task.

ISRU is going to enable us to do the things, we want to do, in Space, to the Moon, Mars, and Beyond, for the rest of time.

**We Dare Not Risk Doing Nothing**

**So how do we get the resources to afford it?**