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roadmap

# BRINGING SPACE DOWN TO EARTH

A Roadmap for Integrating Space  
Resources Into the Global Economy

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Colorado School of Mines  
Golden, Colorado

November 2006

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Front and Back Cover Photo: Courtesy of NASA

From AS17-147-22526 (11 December 1972)

*Astronaut Eugene A. Cernan, commander, makes a short checkout of the Lunar Roving Vehicle (LRV) during the early part of the first Apollo 17 Extravehicular Activity (EVA-1) at the Taurus-Littrow landing site. This view of the "stripped down" LRV is prior to loading up. Equipment later loaded onto the LRV included the ground-controlled television assembly, the lunar communications relay unit, hi-gain antenna, low-gain antenna, aft tool pallet, lunar tools and scientific gear. This photograph was taken by scientist-astronaut Harrison H. Schmitt, lunar module pilot. While astronauts Cernan and Schmitt descended in the Lunar Module (LM) "Challenger" to explore the Moon, astronaut Ronald E. Evans, command module pilot, remained with the Command and Service Modules (CSM) "America" in lunar-orbit.*

## About the Roadmap

In January 2006, the Center for Space Resources at the Colorado School of Mines commissioned the development of this Commercial Space ISRU Roadmap (Roadmap). The purpose of this initiative was to identify ways to accelerate the development of viable business ventures employing space resources, with special emphasis on the commercial development of space solar power.

The central **problem** posed for examination was:

*Whereas there are several potential enterprises that can be profitable in space in the long-term, near-term commercial ventures are more difficult to identify. Are there contemporary-, near- and intermediate-term steps that could generate early commercial investments that lead to the widespread use of space resources on and off the Earth?*

Two questions, with related hypotheses, were selected for investigation and to serve as starting points for assembling the Roadmap. They were:

- Question 1: How can the established Space ISRU technical and business communities more effectively attract outside entrepreneurial and investor interest to develop and help launch actual Space ISRU commercial ventures?
- *Hypothesis:* New pathways for the commercial development of space can be implemented in concert with government space exploration programs.
- Question 2: How can the transfer of information among members of the Space ISRU technical and business communities be improved?
- *Hypothesis:* A new non-governmental entity, The Eighth Continent™ Chamber of Commerce, can be a strong and successful vehicle for traversing those pathways.

In response to this assignment, invited experts from the technical and business communities participated in two workshops held in the spring and summer of 2006 at the Center for Space Resources at the Colorado School of Mines. Mr. Burke O. Fort, on special assignment from his Program Manager duties at the University of Texas Center for Space Research, led these workshops.

This Roadmap is the result. It was publicly presented during the Space Resources Roundtable VIII conference, which was held on October 31 through November 2, 2006, also at the Colorado School of Mines.

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**Into the Global Economy**

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## Introduction

Welcome to *BRINGING SPACE DOWN TO EARTH: A Roadmap for Integrating Space Resources into the Global Economy*. It is the result of a systematic effort to chart pathways along which to accelerate the pace of space ISRU<sup>1</sup> technical and commercial development.

At its base, it is an earnest and, hopefully, praiseworthy attempt at “cross-cultural” communication among twenty-two dedicated professionals from highly diverse backgrounds in the space and business communities. Their objective is to bring about something new and engaging by building a common conceptual ground.

Although unique in many ways, this Roadmap also represents a latest installment within an ongoing dialogue. The genesis of this dialogue is nothing new; indeed, it has been and is the steam that powers humankind’s long record of technological, commercial and social accomplishment. On the other hand, the *topic* of this particular dialogue is relatively new and, to some, is as exciting as those early conversations that led our intellectual evolution from the wheel, through each of the many wonders of the ancient and modern world, to something a little closer in time and closer to home—space travel.

The Apollo Program, and all that preceded it, competed with it, and came from it, is inscribed permanently in the Book of Life. But, as Neil Armstrong spoke for all present both then and before then when he said, “That’s one small step,” he heralded the beginning of the next of an unfathomable number of steps for future generations that were then perched symbolically on his shoulders.

This Roadmap sets forth pathways on which history may record where those steps landed in the process of bringing the cosmos out of the extraordinary and into our everyday experience.

## Overview and Executive Summary

The development of viable business ventures has been a major barrier to commercial investment in space resource development. With few exceptions, the business and investment community has not considered the business potential of space resource development, due to commonly-held, and sometimes mistaken, perceptions of high risk and low return on investment over time when compared with other opportunities. Resource capture and development technology exists, but what seems to be missing is a deeper level of communication between the technical and business communities – one that would lead to a more accurate, mutual understanding of the risk and profit potential involved.

This Commercial ISRU Roadmap is an attempt to bridge that communication gap.

Within this Roadmap is proposed a new campaign, to be known as The Eighth Continent Project™. Its mission is to bring about viable business ventures for the development of new commerce based on the use of space resources.

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<sup>1</sup> ISRU (In Situ Resource Utilization) means making use of available resources. Space ISRU refers to the use of any resource located beyond 100 kilometers above the surface of the Earth. Such resources may be either naturally occurring or man-made.

The central strategy set forth in this Roadmap is to further develop the technology needed for efficient and productive space ISRU operations through a stepwise progression of contemporary-, near- and intermediate-term technology development with profitable *terrestrial*<sup>2</sup> market applications. A portion of the revenues from early technology products would then be reinvested in additional technology development and, with revenue from *their* attendant market applications, fuel subsequent rounds until a “horizon-term”<sup>3</sup> system is technically and financially feasible.

This strategy responds to both (a) NASA’s decision to integrate commercially developed technology into its Moon-Mars exploration program planning and (b) the non-NASA space ISRU customer community emerging within the private sector, other government entities, and academia. This means that NASA funding can contribute to the Roadmap’s success, but will not determine it.

Specific short-term actions are proposed within the Implementation Strategy of this Roadmap to catalyze this proposed approach. They are:

1. Organize a Space ISRU Chamber of Commerce/Trade Association Entity as a comprehensive portal through which the space ISRU technology and business interests may organize and represent themselves collectively as a unified commercial sector;
2. Establish a Space ISRU Think Tank comprised of space ISRU stakeholders committed to collaboratively developing both proprietary and open source space ISRU technology concepts and products for contemporary-, near-, intermediate- and horizon-term commercial markets;
3. Organize a Space ISRU Business Incubator dedicated to creating actual space ISRU businesses and jobs through invited access for new ventures to quality equity sources, quality debt resources, expert business advice, and discounted pricing on business office space, supplies and other infrastructure;
4. Launch a Space ISRU Pontoon Fund as a source of quality equity funding for bridging promising space ISRU technology to early stage/seed funding opportunities;
5. Establish a Space ISRU Business Plan Open Competition in the form of an ongoing, international, prize-centered contest to (a) create actual space ISRU businesses and jobs and (b) generate visibility in both the professional communities and the general public; and,
6. Perpetuate the Lunar Ventures Student Business Plan Competition as a prize-centered contest through which university students (a) create actual space ISRU businesses and jobs, (b) generate visibility in both the professional communities and the general public, and (c) obtain outstanding educational experiences;

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<sup>2</sup> “Terrestrial” is used in this Roadmap to denote assets and activities that exist on Earth; that is, at or below 100 kilometers above the surface of the Earth.

<sup>3</sup> Examples of possible “horizon-term” systems include space solar power, spacecraft repair and consumables resupply services, lunar regolith excavation and processing, among others.

Proposed is an ambitious campaign. It is wholly dependent upon the willingness of the space ISRU community to adopt and commit to it. Doing so will require more cooperation and collaboration, at least at first, than competition, as threshold enabling technologies are developed, technology and interoperability standards are adopted, and rules of commercial engagement are established. Seen through to its completion, this approach will accelerate the arrival of a large, profitable array of expanded and new markets through a cost-efficient sharing within our community of the expense of building the technical and commercial infrastructure required to grow, prosper and mature individual businesses.

This campaign's architecture has heritage. It is based on a business models proven in several hundred of today's highly profitable global markets, including microelectronics and semiconductor manufacturing.

## Roadmap Contexts

### **Capitalism-centered.**

Many would assert that one of the greatest engines of accomplishment devised by humanity is capitalism, which is characterized well for our purposes in the following *Wikipedia* definition:

“Capitalism is an economic system in which the means of production are owned mostly privately, and capital is invested in the production, distribution and other trade of goods and services, for profit in a competitive free market. These include factors of production such as land and other natural resources, labor and capital goods.”<sup>4</sup>

It is the system according to which the authors of this Roadmap operate. It serves as a vehicle for traversing their intellectual territory, and offers many useful signposts and milestones with which to navigate either alone and with others – words like system, capital, trade, profit, free market, natural resources, and labor.

However, although capitalism is the economic context within which this Roadmap resides, the pathways ultimately taken in the development of space ISRU commerce will doubtless include efforts – both competitive and collaborative – from other economic systems. This Roadmap's strategies reflect that likelihood.

### **Not (intentionally) America-centered.**

This Roadmap is not intentionally America-centered, in recognition of the opportunities that are implicit in the abovementioned fact that not all countries operate within a capitalistic system. Every effort has been made to identify prospects within the global marketplace so as to include those that exist within other cultures and sets of rules. For example, countries that are a signatory to the Kyoto Treaty and/or which do not have to deal with America's International Traffic in Arms Regulations (ITAR) constraints merit consideration.

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<sup>4</sup> Capitalism. (2006, September 27). In *Wikipedia, The Free Encyclopedia*. Retrieved 20:54, September 27, 2006, from <http://en.wikipedia.org/w/index.php?title=Capitalism&oldid=78105023>

**Not NASA-centered.**

A less comprehensive, yet important, contextual factor involves the role played by NASA and the entities to which it answers – the White House, the U.S. Congress, and the American people. The scope of the Roadmap includes, but is not limited to, consideration of the commercial opportunities inherent within NASA’s ambitious Moon-Mars exploration vision. Because there currently exists significant disagreement concerning the nature, and even use, of ISRU technology and resources in the Moon-Mars program’s mission architectures, no attempt will be made to predict the ultimate direction of NASA planning. Rather, the full range of rational technical alternatives will be open to consideration.

So, within the caveat this position requires, technology and policy decisions by NASA, as a prospective customer and partner, remain important to us, but in a context that also includes other potential customers and partners.

It is important to note, however, that undertaking the steps laid out in this Roadmap might well prove to be of great benefit to NASA’s Exploration Systems Mission Directorate (ESMD) technology development efforts, accelerating progress beyond what might otherwise be the case. This would, in turn, accelerate the development and use of those technologies for commercial applications.

**Exclusively focused on space ISRU commercialization.**

There is a great deal of recent activity in the space community focused on promoting the development of “space commerce.” Topics exploring virtually every aspect of nearly every conceivable commercial endeavor arguably related to space are being identified, discussed and elaborated; and proposals calling for institutes, programs, and policy studies are many.

This Roadmap is certainly a part of that activity. However, central to the terms of its development is the notion that it should not compete with or duplicate other efforts – rather, that it should complement and advance those efforts. For this reason, this Roadmap is limited to “space ISRU technology and resource commercialization” and pertains to the “commercial exploitation of phenomena that exist physically at least 100 kilometers above the surface of the Earth, including the technology required to reach, process and deliver them to market, regardless of where that market is located.”

**Not technology-specific.**

This is not a technology roadmap. It is a space ISRU commercial venture development roadmap, viewed from a perch overlooking current representative space ISRU technology levels and development trends. Through the 2006 Workshops process, several specific space ISRU technologies were closely examined – not as an end, but as a means for identifying missing elements needed to spawn and sustain a broad commercial emergence.

**Results oriented.**

The aim of this Roadmap is to rapidly generate results in the form of successful and very concrete projects. Its Implementation Strategy details a proposed action plan for doing so, beginning immediately.

## The 2006 Workshops

This Roadmap is the principal product of The 2006 Workshops. The **goal** of the Workshops was to bring those with the technical knowledge of the opportunities of space ISRU technologies and resources together with people who know how to turn ideas into enterprises.

The central **problem** that these “expert-participants” examined was:

*Whereas there are several potential enterprises that can be profitable in space in the long-term, near-term commercial ventures are more difficult to identify. Are there contemporary-, near- and intermediate-term steps that could generate early commercial investments that lead to the widespread use of space resources on and off the Earth?*

Two questions, with attendant hypotheses, were posed for investigation and to serve as starting points for assembling this Roadmap. They were:

- Question 1: How can the established Space ISRU technical and business communities more effectively attract entrepreneurial and investor interest from outside of that community to develop and help launch actual Space ISRU commercial ventures?
- *Hypothesis:* New pathways for the commercial development of space can be implemented in concert with government space exploration programs.
- Question 2: How can the transfer of information among members of the Space ISRU technical and business communities be improved?
- *Hypothesis:* A new non-governmental entity, The Eighth Continent™ Chamber of Commerce, can be a strong and successful vehicle for traversing those pathways.

### Workshop 1

Only technical experts participated in Workshop 1, which was held on May 2-3, 2006, at the Center for Space Resources at the Colorado School of Mines in Golden. They identified “low-hanging fruit;” that is, prospective contemporary- and near-term business ventures that *from a technical standpoint* could be suitable for early commercial investment along a pathway that leads to the widespread use of space ISRU technology and resources on and off the Earth. Potential “low hanging fruit” ventures extracted from that work for further analysis were:

#### Leading to Wireless Power Transmission

- Microwave power relay technology in terrestrial transmission systems
- Power bundled with data connectivity

#### Leading to Renewable Energy Systems

- Systems that enable simultaneous use of land and other facilities used for wind, solar and biomass / agriculture
- Improved power conditioning and storage technologies

#### Leading to Lunar Resource Extraction and Management

- Cryogenic materials management, storage and transfer

- Lunar regolith and rocks as (a) research media, (b) collectibles, and (c) manufactured product constituents (e.g., lunar minerals in commemorative coins, etc.)

#### Serving Existing Space Commerce

- Expanded and strengthened markets for present-day space-oriented tourism, media and robotics companies
  - Tourism (e.g., Zero Gravity Corporation, Space Adventures and Virgin Galactic)
  - Media and Business-to-Business (B2B) Branding (e.g., Ecliptic Enterprises and the Blastoff! Venture)
  - Space Robotics (e.g., iRobot, Caterpillar, McDonald-Detweiler Robotics, Honeybee Robotics and Baker Hughes)
- Commercial opportunities on ISS and other space-based platforms

#### Serving Current and Future Space-Enabling Workforces

- Realignment of aerospace workforce to enable entrepreneurial space commerce
- Education of insurance and risk management industry regarding space operations
- Education of banking, financial and investment industry regarding space operations

During the two months that separated Workshop 1 from Workshop 2, the technical experts met virtually as subgroups assigned to research and develop to the best of their abilities the business case for each of the low-hanging fruit concepts. They were not asked to develop full business plans. Rather, they were tasked with developing for each product a top-level technical characterization, plus their best estimates of the product's purpose (what problem it solves), target customers, revenue streams, potential market size and composition, competition, and other factors affecting financial performance projections. To standardize the structure of each subgroup's work product, the following presentation format was specified:

#### Slide 1. Product Description

- Brief description
- Field(s) of technology (e.g., nano, information, bio, robotics, etc.)
- Ownership of (a) main technology and (b) enabling technologies
- Illustration (*simple* diagrams, photographs, or screen shots)
- How it is built (technical platform, etc.)
- How it works

#### Slide 2. The *Present-Day* Problem Being Solved

- Where's the "pain?" (read: need/want)
- Who is feeling it?
- What problem will the product solve?
- How does the product solve it?

#### Slide 3. Target customers

- Who would buy the product: business or consumer?
- Demographics
- Industry and market segments
- Geographic / regional focus
- Specific examples

Slide 4. Potential market and market size

- Size of market (US\$/year)
- Composition of market/market segments (e.g., pie charts, etc.)
- Historical and future growth (e.g., bar graphs, etc.)

Slide 5. Competition and competitive advantage

- Names of competitors
- Competitive advantages

Slide 6. Bases for Financial Projections

- Projected number of customers or units sold annually in first ten years
- Projected revenue assumptions (consider all potential revenue streams; e.g., sales, tax incentives, IP royalties, etc.)
- Projected expenses assumptions (consider performance of comparable companies, etc.)
- Projected profit assumptions (breakeven point, time to profitability, etc.)

Slide 7. Partnerships and Alliances

- Specific or types of commercial and governmental partners that could help the enterprise reach its objectives
- Useful organizations with which to ally (e.g., Space Resources Roundtable, Lunar Commerce Executive Roundtable, etc.)

Slide 8. Endnotes

- Explanations and References

## Workshop 2

Workshop 2 was held on August 8-9, 2006, again at the Center for Space Resources at the Colorado School of Mines. Joining the Workshop 1 technical experts were six professionals with expertise in entrepreneurship, equity and debt financing, marketing, insurance/risk management, and business law. All of the business experts, two of whom are Canadian, have international experience in their field. With one exception,<sup>5</sup> none of the business experts have any experience in space-related commerce.

One week before Workshop 2, the business experts were provided with the technical experts' inter-workshop low-hanging fruit characterizations. This stimulated meaningful discussions right from the beginning of the session's first day, during which the technical experts presented their work.

On Day 2, the business experts presented their impressions of the Day 1 presentations. They explored desirable market conditions for, and current barriers to, the commercial viability of these prospective ventures. They also characterized specific actions that should be undertaken in order to mature the respective business case for each and generate real interest among prospective investors.

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<sup>5</sup> Insurance and risk management consultant Kelly Alton is agent of record for Zero Gravity Corporation, which is involved in a segment of the emerging space tourism market.

This exercise was useful not only for those technical experts with entrepreneurial aspirations for their business ideas. It also served to identify specific actions, expertise and resources vital to successfully developing the business case for most technology-centered ventures, including many seeking to commercially exploit space ISRU.

This latter result provided the substance from which this Roadmap was assembled.

## Working the Problem

With the context of and process behind the assembly of this Roadmap presented above, this section reports the substance of the interactions among the Workshop expert-participants. Much of what is set forth are remarks made directly during the sessions, while other passages contain the material from books, articles and reports referenced within those remarks.

### Central Questions

Human beings are associative creatures. Although capable at times of something close to original creativity, we most frequently innovate by applying lessons learned in one context to another. Associatively, it follows that the contexts within which a space ISRU commerce aspirant is likely to operate are likely to include the same conditions, opportunities and challenges faced by any other entrepreneurial aspirant.

Dr. George Kozmetsky, the late entrepreneur and educator who founded Teledyne and many other successful enterprises, once declared that four things are needed to produce new ventures:

1. Ideas/technology
2. Entrepreneurs
3. Money/Investors
4. Supporting Technical and Business Infrastructure in Community

These are the core elements around which the opinions, conclusions and proposed actions residing within this Roadmap are framed.

Space ISRU ideas and technology have been a topic of study for several decades within a global community of technical experts working in government labs, corporate R&D centers, and academic institutions. Recognizing its potential, these accomplished professionals have occasionally ventured outside of their areas of expertise to identify ways to attract entrepreneurs and money/investors through whom to “spin off” such technology into commercial service. Yet, to date, few entrepreneurs and investors have committed meaningfully to space ISRU ventures.

Logic suggests, therefore, that adequate levels of one or more of Dr. Kozmetsky’s four elements are missing when it comes to commercially exploiting space resources and attendant space ISRU technology.

As in any emerging commercial opportunity, the underlying idea/technology must be sufficiently “ripe” in order to attract the attention of those with the money and entrepreneurial know-how to successfully bring it to market. Indeed, in capitalistic countries, governments, corporations, and academia frequently sponsor research on “pre-competitive” technology to advance knowledge and hasten the day when that knowledge can be profitably put to work. Indeed, space ISRU

technology and resource management community is prime example of a beneficiary of this pre-competitive “pump-priming” practice. In other words, it appears that there are many good ideas to assess for commercial potential.

At the core of this Space ISRU Commercial Roadmap is the objective of accelerating the process by which human activity expands into space. Although clearly not a business proposition, this goal reflects a **value proposition** that easily translates into the commercial realm:

*For investors faced with a shrinking selection of quality investment opportunities, space ISRU is a new, emerging source of technology and natural resources, the exploitation of which will deliver meaningful returns on investment over acceptable periods of time and within acceptable levels of risk. Unlike traditional “terrestrial” natural resources, the nature and quantity of space resources are virtually limitless, constrained only by the (technological) ability to reach, process and deliver them to market.*

Accordingly, from a present-day perspective, three central questions emerge from Dr. Kozmetsky’s assertion:

1. What space ISRU ideas/technologies may be candidates for commercial investment?
2. What qualities and quantities of space ISRU ideas/technologies and supporting infrastructure must be present in order to attract the levels of entrepreneurial and investor commitment needed to accelerate the pace of space ISRU commercial development?
3. Beginning today, how can the qualities and quantities of space ISRU ideas/technologies needed to attract entrepreneurial and investor commitments be developed and delivered?

### **Examining Question No. 1**

*“What space ISRU ideas/ technologies may be candidates for commercial investment?”*

The technical community has already received appreciated, but relatively modest, “pre-competitive” development grant support to study the design, installation and operation of space ISRU technologies. This has produced a body of knowledge that for the most part is in the public domain and joins a small but growing amount of productive proprietary ISRU research. By selecting from among these intellectual assets those that have the potential for near-term revenue generation – particularly those addressing “terrestrial” markets – the stream from this revenue may be used to both (a) cost-share the development of later technology required for space-rated ISRU operations and (b) accelerate the date on which it may be put into productive service.

The Workshop process produced a number of present-day industries with actual markets or market potential for space ISRU technology and resources. They are:

- Agriculture
- Banking and Financial
- Biotechnology
- Chemicals
- Construction
- Consumer Goods and Retailing
- Education
- Electronics
- Energy and Power
- Entertainment and Sports
- Environmental Protection
- Human Resource Development
- Information Technology
- Insurance and Risk Management
- Logistics
- Manufacturing
- Media
- Navigation and Geo-Positioning
- Natural Resource Extraction and Management
- Robotics and Autonomous Operations
- Spacecraft Servicing
- Telecommunications
- Tourism
- Pharmaceuticals
- Resource Management and Conservation, Recycling
- Weather Forecasting and Meteorology

Of these, a number were more closely examined, the result of which was the development of the near-term “low-hanging fruit” venture concepts presented and discussed in Workshop 2. Brief non-proprietary descriptions are provided below. Note, however, that neither these concepts nor the industries listed above are considered to be exhaustive characterizations of space ISRU commercial scope or potential.

#### Super-Cooled Computer Chips

- *Technology:* Cryogenic materials management, storage and transfer
- *Market:* Computer Industry
  - *Idea:* Computer chip speeds made faster by lowering the temperature of the chip components
  - *Problem solved:* Significantly increase processor efficiency and speed
- *Horizon-term space ISRU application:* Development of lunar natural resource technology and resource extraction, processing and use

#### Distributed Wind/Solar/Stored-Water Power

- *Technology:* Develop small scale generation, transmission and storage systems
- *Market:* Developing countries without established power grids
  - *Idea:* Improved power generation, conditioning and storage systems at small power levels in distributed, off-grid communities
  - *Problem Solved:* Reliable, constant, clean electrical energy; small wireless power transmission technology demonstrations
- *Horizon-term space ISRU application:* Development of properly-scaled, sustainable space power and energy storage systems

#### Moon Rock & Soil Commodities

- *Technology:* Commercial lunar sample return
- *Market:* Purchasers of precious commodities, like gold, silver, etc.
  - *Idea:* Lunar regolith and rocks as (a) research media, (b) collectibles, and (c) manufactured product constituents (e.g., lunar minerals in commemorative coins)
  - *Problems Solved:*
    - Satisfy desire to own commodities that hold value intrinsically for purposes of wealth accumulation and investment hedging

- Satisfy desire to own something novel and rare
- Deeper scientific understanding of lunar environment
- *Horizon-term space ISRU application:* Development of lunar natural resource technology and resource extraction, processing and use

#### Foamed Aluminum

- *Technology:* Recycling of aluminum into sheets aluminum in foamed form
- *Market:* Automotive Industry
  - *Idea:* Use of recycled sheets of aluminum with small internal air pockets in automotive in door panels, front hoods, bumpers, roof panels
  - *Problem Solved:* Inexpensive and effective structural reinforcement and energy absorption
- *Horizon-term space ISRU application:* On-orbit reprocessing of discarded space junk to produce cheap structural materials for on-orbit fabrication of large space-structures

#### Wireless Power Transmission

- *Technology:* Small-scale, low-power wireless power transmission and relay for terrestrial electrical power systems
- *Markets:* Remote, off-grid communities; and remote, off-grid power generation facility owners
  - *Idea:* Wireless power transmission as substitute for land lines in rugged and remote territories
  - *Problems Solved:*
    - Access to affordable, clean, and plentiful power
    - Ability to transit power from generation sites (e.g., wind) to transmission lines
- *Horizon-Term space ISRU application:* Development of space solar power systems

To repeat, this is not a technology roadmap. These potential commercial ventures were not selected based on a methodical forecast of technical or commercial success. They were selected to facilitate the workshop dialogue and roadmap development process, and are presented here for illustrative purposes only.

Looking back from a point many years in the future, one will be able to see the various technological routes that were taken – some successfully, some not. The technology will be what it will be; and what that is will be determined not only by the march of technological advances, but also by its ability to survive, develop, and transform itself into productive wealth within the global marketplace.

**Lesson No. 1: As technology and knowledge develop through exploration and research, newly emerging technological concepts should be identified on a regular basis.**

### **Examining Question No. 2**

*“What qualities and quantities of ideas/technologies and supporting infrastructure must be present in order to attract the levels of entrepreneurial and investor commitment needed to accelerate the pace of space ISRU commercial development?”*

There is a significant “culture gap” between the space ISRU technical community and the entrepreneurial community. The former is accustomed to working with decadal and longer project horizons with government funding and the discipline imposed by scientific and engineering principles; the latter employs the power of the free markets and the creativity of entrepreneurship to recover meaningful profit within five or fewer years.

Accordingly, Objective One of this Workshop 2 was to narrow, and perhaps occasionally bridge, that gap. Deservedly or not, those serious about creating space ISRU ventures are frequently confronted by the “giggle factor” the moment they approach venture capitalists with their concept proposals. When this happens, the space ISRU entrepreneur has precious few seconds to rebut this presumption.

The Workshop 2 business expert-participants provided a great deal of advice on this issue, based on the giggles that they had witnessed in other markets. Their message was essentially this: In order to shunt aside this initial handicap, much more than a full understanding of the idea/technology in play must be mastered. Equal, if not more, attention must be given to the remaining three of Dr. Kozmetsky’s four elements: entrepreneurs, money and support infrastructure.

## Entrepreneurs

According to Geoffrey Moore, author of *Crossing the Chasm*,<sup>6</sup> entrepreneurs are essentially a technologist’s first investor. They are visionaries with both skills and some money looking for breakthrough ideas/technologies that enable strategic leaps forward to capture order-of-magnitude returns on their investment.

As a general rule, technologists do not find entrepreneurs; rather, entrepreneurs find technologists’ ideas (and then the technologists) through their own handpicked network of what Moore calls “innovators” and “technology enthusiasts.” Innovators and technology enthusiasts occupy the first “early adopter” market segments within the “Technology Adoption Life Cycle”<sup>7</sup> and are defined as those who buy new product concepts very early in their life cycle simply because “they are intrigued with any fundamental advance and often make a technology purchase simply for the pleasure of exploring the new device’s properties.”<sup>8</sup>

**Lesson No. 2: Technologists can increase the chance of being found by entrepreneurs by capturing the innovator and technology enthusiast communities with an early version of a product and its attendant “buzz” within those communities’ networks.**

<sup>6</sup> In addition to the comments of the Workshop 2 business experts, two resources provided much of the material used to illustrate and apply Dr. Kozmetsky’s “four things” to the space ISRU commercial context. Recommended by two of those experts, they are (a) Rob Adams, *A Good Hard Kick In The Ass: Basic Training for Entrepreneurs*, Crown Business (hardback, 2002) and (b) Geoffrey A. Moore, *Crossing The Chasm: Marketing and Selling Disruptive Products to Mainstream Customers*, Collins Business Essentials (paperback, 2006).

<sup>7</sup> The “Technology Adoption Life Cycle” is the model upon which Moore’s book is built. It characterizes different classes of customers (Innovators, Early Adopters, Early Majority, Late Majority, and Laggards) for a product in terms of their risk tolerance as a function of when after product introduction they are likely to purchase.

<sup>8</sup> Moore, p. 12. The only major difference between innovators and technology enthusiasts is that the latter are not technologists.

## Execution Intelligence

Sometimes, entrepreneurs are innovators or technology enthusiasts themselves. Whether an entrepreneur or hoping to be found by one, a technologist must know what makes a good one.

A successful entrepreneur must have a top-rate team and know his/her “market space.” Both elements require agility and constant reassessment.

A top-rate team provides both guidance and legitimacy to the venture. Good teams possess what Rob Adams, in *A Good Hard Kick in the Ass*, terms “execution intelligence.”<sup>9</sup> Execution intelligence should be present in the people within the entrepreneur’s Board of Directors, advisor network, and staff. It is comprised of:

- Domain intelligence – experience in specific market space and with the prospective customers within it
- Experience surviving and thriving in fast-growth markets
- Experience surviving and thriving in highly competitive markets
- Experience anticipating markets changes and managing those changes well
- The right expertise in marketing, sales, and product development
- Leadership skills

**Lesson No. 3: Successful entrepreneurs must have people committed to his/her venture who can “execute on the idea.”**

Adams punctuates the primacy of execution intelligence in an entire chapter, the title of which is “Investors Fund Great Teams – Not Business Plans.”<sup>10</sup> Indeed, he recommends using the business plan only as a “leave behind” to reinforce the message pitched to a prospective investor.

## Market Validation

Another essential characteristic of a successful entrepreneur is a deep belief that one’s “market space” can never be known thoroughly enough. Customers’ needs constantly change. So do the identity and tactics of the competition and many other factors that go into delivering responsive product solutions.

As central as Adams’ execution intelligence, “market validation” is an essential practice of the successful entrepreneur, which if fully practiced will significantly reduce a venture’s market risk. “Market validation” is a process comprised of several steps:

1. **Locate the customer “pain”** – the urgent need or want – for which the entrepreneur can provide a solution; the more pressing the pain, the better.
2. **Verify that the pain is there**, and characterize projected market size and trend directions, using secondary research found on the Internet, in analysts’ reports industry press articles, etc.
3. **Explore the pain** by undertaking quantified market

**Lesson No. 4: A successful entrepreneur practices “market validation;” that is, continuously assesses a broad range of primary and secondary data characterizing targeted markets and the people within them who make purchase decisions.**

<sup>9</sup> Adams, p. 27.

<sup>10</sup> Adams, pp. 125-154.

research, in the form of structured questionnaires, to locate market segments with the “greatest pain”

4. **Envision the best solution** by testing within target market segments those who are “quality influencers;” that is, members of the market segment who expressed in the questionnaire interviews an “especially distressing pain, a high degree of interest in a possible solution, and a willingness to be contacted again.”<sup>11</sup>
5. **Establish credibility** through marketing to “leverage influencers” – thought leaders, analysts, consultants and authors whom you want to be excited about your product.

When a venture reaches the fifth step, then it is primed to be viable in the marketplace. However, the understanding of the market at this point is a mere snapshot; and it is time to start the process all over again to develop even more effective strategies for knowing one’s customers.

## Entrepreneurship in Big Organizations

Entrepreneurship, and the agility it requires, is not the sole province of small organizations. Big companies can act like start ups, too, by:<sup>12</sup>

- Making sure that everyone in the company is creating value
- Continually validating markets
- Communicating a common vision
- Align new products with the sales model
- Harnessing the entrepreneurial energy within the organization
- Cutting bureaucracy to take risks and enable decisions to be made and acting upon quickly
- Stick to the organization’s core competency
- Create smaller, dynamic units within the organization
- Adequately support company R&D

**Lesson No. 5:**  
**Entrepreneurship can be successfully practiced within a large, established organization, frequently with better results if the organization possesses skilled innovators and technologists (Lesson No. 2), execution intelligence (Lesson No. 3), and continually undertakes market validation research (Lesson No. 4).**

## Money, Investors and Value Inflection Points

As stated above, the entrepreneur is frequently the technologist’s first investor. It follows that many of the lessons pertaining to entrepreneurs apply to investors.

Investors provide capital to a venture. They look for right-sized and right-timed opportunities for returns on their investments.

Investors are entrepreneurial. They prefer to fund ventures that have created excitement in their early adopter market segments, have assembled teams that can execute on the idea, and practice continuous market validation research.

<sup>11</sup> Adams, p. 61.

<sup>12</sup> Adams, pp. 262-3.

Entrepreneurs seek capital with which to grow their venture. They look for right-sized and right-timed funding to take the venture from one point to another in the process of chasing viable market space.

The success of a venture is totally dependent on finding investors whose requirements sync with the venture's requirements. The more perfect the match up, the better the chances of success for both investor and entrepreneur.

A match occurs when the investor's goals and requirements are the same as the venture's ability to deliver on them. In a quality investment relationship, that ability is calibrated in terms of the venture's "value inflection points." Value inflection points are related to the "execution intelligence" described above. They are execution milestones, the reaching of which represents both (a) the raising the venture's valuation, and (b) the mitigation of the venture's risk in the eyes of follow-on investors.

For example, for a venture in the seed funding stage, reaching the point where the market for the product has been validated and where a profitable business model is established is a value inflection point that would entitle it to approach Series A investors, who are interested in profiting from financing the work needed to get the first product to paying customers (which is a next stage value inflection point, signaling the venture's ripeness for Series B funding, and so on).

Other value inflection points can be, among many others:

- Prototyping the product,
- The hiring of high quality senior executives and key advisors,
- The hiring of quality managers and individual contributors,
- Signing up brand name customers,
- Establishing strategic partnerships with entities that will speed introduction in key markets, and
- Lining up certain types of investors, such as lead, strategic and others with important expertise and contacts

*Ahead of the commitment to fund*, it is advisable for the entrepreneur and investor to agree in writing to a clear and mutually-defined set of anticipated value inflection points and their timing, related to the nature and timing of the investor's goals and expectations. Although investors and entrepreneurs alike prefer a rapid time-to-market strategy, the better investors prefer to fund great teams pursuing viable market space and will not pressure those teams to deliver value that does not match the agreed-to value inflection point sequence and schedule.

**Lesson No. 6: Both investors and entrepreneurs prosper when the right-sized investment, in exchange for an appropriate amount of equity, is matched to the anticipated execution of a well-conceived value inflection point strategy and the investor's ROI goals.**

Entrepreneurs generally find and approach investors, although some (mostly large dollar amount) investors actively hunt for quality investment opportunities.

Ventures should seek investors who provide not only the right kind of capital at the right moment for the right valuation, they should also add to the product's market excitement and the venture's execution intelligence. An investor is a partner with a particular role, which varies with the type of investor. For example:

- The **lead investor**, as the major investor, provides more than the majority of the new money obtained in a funding round. A lead investor provides a term sheet, which establishes the venture's valuation and makes it easier to attract other investors to fill out the funding of the round.
- **Strategic investors** provide both funding and business credibility, which raises value.
- **Other investors** may lack the magnitude of the commitment that lead investors make, or the reputation in the markets that strategic investors provide. But they should be viewed as valuable members of the team as well, as they can and do bring unique skills, experiences, and contacts to its execution intelligence.

**Lesson No. 7: In addition to the funding, a successful entrepreneur wants from an investor a smart and connected addition to his/her team.**

## Infrastructure

Simply put, infrastructure is a collection of supporting resources that a venture should have “in its own back yard.” Although modern travel, telecommunications and the Internet have served to expand the size of that back yard, there are still some elements that must be present within a 45-minute land route commute.

That backyard should be home to an established community of the people and resources who are needed for the venture to succeed. For example, technology-centered ventures should look for areas with pools of *technology-savvy*:

- Engineers and technologists
- Entrepreneurial talent (e.g., experienced Chief Technology Officers and Chief Financial Officers)
- Fundraising know-how (e.g., venture capitalists, bankers, and marketing agencies)
- Experienced board-, officer- and manager-level leadership skill
- Managerial and administrative talent
- Consultative talent (e.g., academics, commercial and IP attorneys, survey research firms, and accountants)
- Entry-level employees and employee recruitment networks (e.g., universities with strong engineering and business colleges)
- Networking contacts

The backyard should also meet other venture needs, such as:

- Ready and inexpensive access to high speed Internet,
- Easy access to adequate air transportation and, if shipping, rail and highway systems,
- Supportive (or, at least, “do no harm”) government,
- Adequate design/test/prototype/production capability, and
- Lifestyle conditions that match those desired by the people who work for the venture.

**Lesson No. 8: A venture must be located in a place that best provides the intellectual, operational and lifestyle assets needed and wanted by its team.**

### Examining Question No. 3

*“Beginning today, how can the qualities and quantities of space ISRU ideas/technologies needed to attract entrepreneurial and investor commitments be developed and delivered?”*

At this time there are a number of individuals and groups within our community who have taken the initiative to explore and organize various aspects of space ISRU commerce. Some focus on developing and promoting the use of certain systems or locales, such as space solar power and lunar resources. Others concentrate on identifying and removing legal/regulatory barriers. Examples of this sort of endeavor include efforts to establish a modern space property ownership regime or to craft an appropriate set of rules governing space tourist safety. Yet others are establishing dialogues within our community’s constituent professional communities. The Space Resources Roundtable and the Lunar Commerce Executive Roundtable illustrate this sort of initiative.

An original premise of The 2006 Workshops involved a proposal to create a “new non-governmental entity, The Eighth Continent™ Chamber of Commerce.” As meant in this statement, a “chamber of commerce” would be like any other chamber – an inclusive, membership-based entity around which a business community is organized, represented and promoted. But, rather than focus on a particular city or region, The Eighth Continent™ Chamber of Commerce would organize, represent and promote the space ISRU technology and resource commercialization community.

The charge given to the Workshop expert-participants included consideration of two hypotheses which, when combined, state that, this new chamber entity “can be a strong and successful vehicle for traversing”... “[n]ew pathways for the commercial development of space [and] can be implemented in concert with government space exploration programs.”

However, the Workshop process led to a conclusion that both confirms and *broadens* the scope of these hypotheses. Simply, more than a “chamber of commerce” type entity is required.

### Recommended Response

The eight lessons set out above serve as guidance to the Roadmap process. Taken together, they suggest central strategies and actions by which to implement them.

Recommended are four Roadmap Strategies, each corresponding to and promoting the acquisition and strengthening within the space ISRU community of Dr. Kozmetsky’s four elements:

Strategy 1: Develop and exploit early space ISRU **ideas/technologies** in terrestrial contemporary- and near-term markets; and then use the revenues generated to develop next-step technologies, investor interest, entrepreneurial interest, and supporting infrastructure, through which intermediate- and horizon-term space ISRU technology and resources will be developed and employed in the global economy

Strategy 2: Identify, recruit and engage Space ISRU **entrepreneur**-visionaries

Strategy 3: Increase **investor** awareness of opportunity, and reduce perceived business risk, of Space ISRU ventures through education, training and outreach, as well as actual investment opportunities

Strategy 4: Locate, catalog, engage and, where necessary, develop supporting **infrastructure**

## Action Plan

Crucial to the development of an effective action plan is an awareness of its relationship with other initiatives within the community. To optimize its effectiveness, every effort must be made to complement and further – and not duplicate or compete with – those initiatives.

For our community, it is particularly important to recognize that there is already a great deal of talent focused on space ISRU technology/ideas. Although investing more attention on technology/idea development would be beneficial and is included in this Action Plan, what is more urgently needed is the inclusion in our community of experienced technology entrepreneurs, seasoned technology venture capitalists, and the infrastructural resources of cities and regions that can offer what an emerging space ISRU commercial sector needs to succeed.

To accomplish this, a broader range of people and organizations must enter the effort. How those needed resources are to relate to another is reflected in the following recommended actions:

- Action 1: Organize a Space ISRU Chamber of Commerce/Trade Association Entity as a comprehensive portal through which space ISRU technology and business interests may organize and represent themselves collectively as a unified commercial sector
- Goal: To promote the development of ideas/technologies, entrepreneurial skills, funding, and support infrastructure for the Space ISRU commercial community
- Action 2: Establish a Space ISRU Think Tank as a consortium comprised of space ISRU community stakeholders/partners committed to *collaboratively* developing both proprietary and open source space ISRU technology concepts and products for contemporary-, near-, intermediate- and horizon-term commercial markets
- Goals:
    - To develop specific Space ISRU technologies, including through the “reverse engineering” of horizon Space ISRU system designs to identify intermediate- and near-term technologies needed to ultimately build the horizon system technologies; and
    - To develop specific Space ISRU products, including through the “value engineering” of existing goods and services to identify applications in contemporary-, near-, intermediate- and horizon-term Space ISRU markets.
- Action 3: Organize a Space ISRU Business Incubator as a program dedicated to creating actual space ISRU businesses and jobs through invited access for new ventures to quality equity sources, quality debt resources, expert business advice, and discounted pricing on business office space, supplies and other infrastructure
- Goal: To generate actual, successful businesses

- Action 4: Launch a Space ISRU Pontoon Fund as a source of quality equity funding for bridging promising space ISRU technology to early stage/seed funding opportunities
- Goal: To provide equity resources for the Open Business Plan Competitions, Student Business Plan Competitions, and Business Incubator programs, as well as access to later stage funding rounds
- Action 5: Establish a Space ISRU Business Plan Open Competition as a periodic, international, and prize-centered contest to (a) create actual space ISRU businesses and jobs and (b) generate visibility in both the professional communities and the general public
- Goals:
    - To generate actual businesses and jobs
    - To generate visibility in both the professional communities and the general public
- Action 6: Perpetuate the Lunar Ventures Student Business Plan Competition as an annual, prize-centered contest through which university students (a) create actual space ISRU businesses and jobs, (b) generate visibility in both the professional communities and the general public, and (c) obtain outstanding educational experiences
- Goals:
    - To provide outstanding educational experience
    - To generate actual businesses and jobs
    - To generate visibility in both the professional communities and the general public

Specific details of this Action Plan are set forth in the following Implementation Strategy section of this Roadmap.

## Implementation Strategy

Central to the goal of successfully adopting the lessons learned through this road mapping process is to rapidly generate results in the form of successful and very concrete projects. This Implementation Strategy details a proposed action plan for doing so, beginning immediately.

### Premise

The private sector has the capital, the organization, and the management talent needed to undertake the task of creating a vibrant Space ISRU marketplace, but is constrained by an inability to look at the Space ISRU community in a comprehensive way. The Space ISRU technical community, on the other hand, has the right motives and perspective, but lacks the necessary business and financial resources. The solution is to integrate the two into a single comprehensive campaign.

### Overall Goal

To organize and constructively engage interested elements of the Space ISRU community in global commerce.

## Objective

Develop and expose a continuing stream of fresh ideas/technologies with commercial promise to receptive entrepreneurs, investors, and infrastructural resources.

## Central Strategies

- Strategy 1: Develop and exploit early space ISRU **ideas/technologies** in terrestrial contemporary- and near-term markets; and then use the revenues generated to develop next-step technologies, investor interest, entrepreneurial interest, and supporting infrastructure, through which intermediate- and horizon-term space ISRU technology and resources will be developed and employed in the global economy
- Strategy 2: Identify, recruit and engage Space ISRU **entrepreneur**-visionaries
- Strategy 3: Increase **investor** awareness of opportunity, and reduce perceived business risk, of Space ISRU ventures through education, training and outreach, as well as actual investment opportunities
- Strategy 4: Locate, catalog, engage and, where necessary, develop supporting **infrastructure**

## Action Plan: The Eighth Continent Project™

### Action 1: Organize a Space ISRU Chamber of Commerce/Trade Association Entity

*Role and scope* A comprehensive portal through which space ISRU technology and business interests may organize and represent themselves collectively as a unified commercial sector

*Kozmetsky Elements(s)* Infrastructure

*Goal* To promote the development of ideas/technologies, entrepreneurial skills, funding, and support infrastructure for the Space ISRU commercial community

*Objectives/Roadmap Traceability*

- Identify newly emerging ideas/technologies (Lesson No. 1)
- Help generate buzz for early-stage space ISRU products in innovator and technology enthusiast market segments (Lesson No. 2)
- Teach, develop, support, and promote “execution intelligence” processes and resources for space ISRU entrepreneur community (Lesson No. 3)
- Teach, develop, support and promote “market validation” processes and resources for space ISRU entrepreneur community (Lesson No. 4)
- Promote and support Lessons 2 (early buzz), 3 (execution intelligence), and 4 (market validation) activities in all sizes of entrepreneurial

- organizations (Lesson No. 5)
- Extend Lessons 2 (early buzz), 3 (execution intelligence), and 4 (market validation) activities to space ISRU investor community (Lesson No. 6)
- Help space ISRU entrepreneurs locate and partner with quality investors who can bring to ventures both execution intelligence and valuable contacts, in addition to funding (Lesson No. 7)

*Programs*

In Touch: Space ISRU Community Resources liaison:

- Innovator+Early Adopter Forum
- Science, engineering and technology
- Higher education
- IP and commercial practice attorneys
- Workforce talent pools and training programs
- Venture capitalists
- Commercial banks
- Entrepreneurial corporate officers (CTOs, CFOs, etc.)
- Connectivity
- Government

Space ISRU Public and Media Relations

Help Desk; conferences, classes and consultation; prospective topics:

- Execution Intelligence – putting together a solid team
- Market Validation – define your market space, know your customers well
- Market Entry and Market Share Capture – getting into market appropriately and quickly
- Capitalization Strategies – raising just the right amount of money at value inflection points; avoiding equity dilution
- Effective Marketing (Is Not Just Advertising)

R&D Support

- Standards development
- Industry surveys, market analyses; statistics
- Law and Public Policy (global)
  - Incentives (loans, grants, tax breaks)
  - Government and foundation grants
  - Legislative updates

*Revenue Sources*

Membership dues  
 Charitable contributions  
 Advertising income  
 Conference fees  
 Course tuition and fees  
 Publication subscriptions  
 Market survey research fees  
 Benefits of IRS tax-exemption  
 Corporate and government grants (e.g., workforce development, education/outreach)

**Action 2: Establish a Space ISRU Think Tank**

<i>Role and Scope</i>	A consortium comprised of space ISRU community stakeholders/partners committed to <i>collaboratively</i> developing both proprietary and open source space ISRU technology concepts and products for contemporary-, near-, intermediate- and horizon-term commercial markets
<i>Kozmetsky Element(s)</i>	Ideas/Technologies, Entrepreneurs
<i>Goals</i>	<p>To develop specific Space ISRU technologies, including through the “reverse engineering” of horizon Space ISRU system designs to identify intermediate- and near-term technologies needed to ultimately build the horizon system technologies.</p> <p>To develop specific Space ISRU products, including through the “value engineering” of existing goods and services to identify applications in contemporary-, near-, intermediate- and horizon-term Space ISRU markets.</p>
<i>Objectives/ Roadmap Traceability</i>	<ul style="list-style-type: none"> <li>▪ Identify newly emerging ideas/technologies (Lesson No. 1)</li> <li>▪ Develop new ideas/technologies (Lesson No. 1)</li> <li>▪ Teach, develop, support, and promote “execution intelligence” processes and resources for space ISRU entrepreneur community (Lesson No. 3)</li> <li>▪ Teach, develop, support and promote “market validation” processes and resources for space ISRU entrepreneur community (Lesson No. 4)</li> <li>▪ Promote and support Lessons 2 (early buzz), 3 (execution intelligence), and 4 (market validation) activities in all sizes of entrepreneurial organizations (Lesson No. 5)</li> <li>▪ Extend Lessons 2 (early buzz), 3 (execution intelligence), and 4 (market validation) activities to space ISRU investor community (Lesson No. 6)</li> <li>▪ Identify locations for major space ISRU venture development (Lesson No. 8)</li> </ul>
<i>Programs</i>	<p><u>Internal Research and Development</u></p> <ul style="list-style-type: none"> <li>• Basic Research – proprietary to Think Tank partners</li> <li>• Early Applied Research – proprietary to Think Tank partners</li> <li>• Technology Development– proprietary to Think Tank partners</li> </ul> <p><u>Open Business Plan Competitions</u></p> <ul style="list-style-type: none"> <li>• Call for proposals in open competition format</li> <li>• Entry fees charged</li> <li>• Seed capital prizes for winning responses</li> </ul> <p><u>Student Business Plan Competitions</u></p> <ul style="list-style-type: none"> <li>• Call for proposals in competition limited to university student teams</li> <li>• No entry fees charged</li> <li>• Seed capital prizes for winning responses</li> </ul>

*Revenue Sources* Partners' equity  
Intellectual property royalties  
Program income (e.g., competition entry fees, speaking honoraria)  
Sales of equity of successful businesses

### **Action 3: Organize a Space ISRU Business Incubator**

*Role and Scope* A program dedicated to creating actual space ISRU businesses and jobs through invited access for new ventures to quality equity sources, quality debt resources, expert business advice, and discounted pricing on business office space, supplies and other infrastructure

*Kozmetsky Element(s)* Entrepreneurs, Money, Infrastructure

*Goal* To generate actual, successful businesses

*Objectives/  
Roadmap  
Traceability*

- Identify newly emerging ideas/technologies (Lesson No. 1)
- Develop new ideas/technologies (Lesson No. 1)
- Help generate buzz for early-stage space ISRU products in innovator and technology enthusiast market segments (Lesson No. 2)
- Teach, develop, support, and promote “execution intelligence” processes and resources for space ISRU entrepreneur community (Lesson No. 3)
- Teach, develop, support and promote “market validation” processes and resources for space ISRU entrepreneur community (Lesson No. 4)
- Help space ISRU entrepreneurs locate and partner with quality investors who can bring to ventures both execution intelligence and valuable contacts, in addition to funding (Lesson No. 7)

*Revenue Sources* Intellectual property royalties  
Program income (e.g., competition entry fees, speaking honoraria)  
Corporate and government grants (e.g., workforce training, etc.)  
Sales of equity of successful businesses

### **Action 4: Launch a Space ISRU Pontoon Fund**

*Role and Scope* Source of quality equity funding for bridging promising space ISRU technology to early stage/seed funding opportunities

*Domain(s)* Money

*Goal* To provide equity resources for the Open Business Plan Competitions, Student Business Plan Competitions, and Business Incubator programs, as well as access to later stage funding rounds:

- Early stage/seed
- Angels

- Series A-n
- IPO

*Objectives/  
Roadmap  
Traceability*

- Help tailor optimal financial matches between quality space ISRU investors and space ISRU entrepreneurs (Lesson No. 7)
- Help space ISRU entrepreneurs locate and partner with quality investors who can bring to ventures both execution intelligence and valuable contacts, in addition to funding (Lesson No. 8)

*Revenue Sources*

Partner equity  
Earnings from equity interest retained in each venture served

### **Action 5: Establish a Space ISRU Business Plan Open Competition**

*Role and Scope*

A periodic, international, and prize-centered contest to (a) create actual space ISRU businesses and jobs and (b) generate visibility in both the professional communities and the general public.

*Kozmetsky  
Element(s)*

Ideas/Technologies, Entrepreneurs, Money

*Goal*

To generate actual businesses and jobs; to generate visibility in both the professional communities and the general public

*Objectives/  
Roadmap  
Traceability*

- Identify newly emerging ideas/technologies (Lesson No. 1)
- Develop new ideas/technologies (Lesson No. 1)
- Help generate buzz for early-stage space ISRU products in innovator and technology enthusiast market segments (Lesson No. 2)
- Teach, develop, support, and promote “execution intelligence” processes and resources for space ISRU entrepreneur community (Lesson No. 3)
- Teach, develop, support and promote “market validation” processes and resources for space ISRU entrepreneur community (Lesson No. 4)
- Help space ISRU entrepreneurs locate and partner with quality investors who can bring to ventures both execution intelligence and valuable contacts, in addition to funding (Lesson No. 6)

*Programs*

Open elimination rounds, closed finalist rounds (to protect proprietary interests); Grand Prize:

1. High quality Pontoon or Early Stage/Seed Funding
2. Resources of Space ISRU Business Incubator Program
3. Prosecution of first patent

*Revenue Sources*

Entry fees  
Participating Pontoon Fund investors’ equity  
Charitable donations  
Corporate and government grants  
Sales of equity of successful businesses

**Action 6: Perpetuate the Lunar Ventures Student Business Plan Competition**

<i>Role and Scope</i>	An annual, prize-centered contest through which university students (a) create actual space ISRU businesses and jobs, (b) generate visibility in both the professional communities and the general public, and (c) obtain outstanding educational experiences.
<i>Kozmetsky Element(s)</i>	Ideas/Technology, Entrepreneurs, Money, Infrastructure
<i>Goal</i>	To provide outstanding educational experience; to generate actual businesses and jobs; to generate visibility in both the professional communities and the general public
<i>Objectives/ Roadmap Traceability</i>	<ul style="list-style-type: none"> <li>▪ Identify newly emerging ideas/technologies (Lesson No. 1)</li> <li>▪ Develop new ideas/technologies (Lesson No. 1)</li> <li>▪ Help generate buzz for early-stage space ISRU products in innovator and technology enthusiast market segments (Lesson No. 2)</li> <li>▪ Teach, develop, support, and promote “execution intelligence” processes and resources for space ISRU entrepreneur community (Lesson No. 3)</li> <li>▪ Teach, develop, support and promote “market validation” processes and resources for space ISRU entrepreneur community (Lesson No. 4)</li> <li>▪ Help space ISRU entrepreneurs locate and partner with quality investors who can bring to ventures both execution intelligence and valuable contacts, in addition to funding (Lesson No. 7)</li> </ul>
<i>Programs</i>	<p>Open elimination rounds, closed finalist rounds (to protect proprietary interests); Grand Prize:</p> <ol style="list-style-type: none"> <li>1. High quality Pontoon or Early Stage/Seed Funding</li> <li>2. Resources of Space ISRU Business Incubator Program</li> <li>3. Prosecution of first patent</li> </ol>
<i>Revenue Sources</i>	<p>Participating Pontoon Fund investors’ equity Charitable donations Corporate and government grants Leveraged by students’ academic institutions and sponsors Sales of equity of successful businesses</p>

## Conclusion

Within this Roadmap we have set forth an approach by which to accelerate the development of viable business ventures employing space resources to, as its title suggests, integrate those resources into the global economy.

Appropriately, how well the Roadmap ultimately performs is a function of how well we have taken our own advice. How well have we “validated the market” for The Eighth Continent Project™? Is there sufficient “execution intelligence” available to effectively carry out its Implementation Strategy?

The answer lies with us all.

This Roadmap sets forth an inclusive process. Becoming involved is like making a pledge during your public television or radio station’s annual fund drive. If you are a part of this community, if this Roadmap presents a strategy that you find valuable, please become involved in whatever way you can by contacting:

The Eighth Continent Project™ Steering Group  
Center for Space Resources  
Colorado School of Mines  
1500 Illinois Street  
Golden, Colorado 80401  
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## Appendix: Expert-Participants of The 2006 Workshops

**Angel Abbud-Madrid, Ph.D.** is the Director of the Center for Space Resources at the Colorado School of Mines, where he also holds an appointment as Associate Research Professor in the Department of Chemical Engineering. Dr. Abbud-Madrid has more than 17 years of experience in space related projects, including conducting combustion and fire suppression research in a variety of NASA's microgravity facilities, including drop towers, parabolic-flight aircraft, and orbiting spacecraft. He was the Lead Scientist and Project Manager of the Water Mist Fire Suppression experiment that was flown on the STS-107 mission of the Space Shuttle *Columbia*. In 2004, Dr. Abbud-Madrid received the prestigious NASA Astronauts' Personal Achievement Award, which is given by NASA's astronaut corps for his outstanding contributions to the success of human space flight missions.

**Kelly Alton** is a Risk Management Consultant with United Risk Solutions, Inc., of Medford, Oregon. A graduate of the United States Air Force Academy and third generation Air Force pilot, he specializes in insurance and risk management for the aviation industry. Mr. Alton also has unique experience in space tourism ventures and counts the Zero Gravity Corporation among his space tourism clients.

**Richard Amato, M.B.A.**, recently left the Clean Energy Incubator, Inc., where he served as its Director, to lead a new renewable energy company, Venti Energy. Mr. Amato specializes in developing the potential of clean energy technologies through entrepreneurial ventures that minimize the depletion of natural resources, maximize the use and value of renewable resources, and further U.S. energy independence. He brings his training and experience as both a business leader and mechanical engineer to these tasks.

**Brad Blair** is a Ph.D. candidate at the Colorado School of Mines. As a specialist in the areas of mining technology, space resources and space commercialization, he has provided consultation to Raytheon, NASA Peer Review Services, DigitalSpace and SysRAND Corporation. Mr. Blair has published over 25 papers on topics related to engineering and economic aspects of planetary in-situ resource utilization, including systems engineering for mining propellants on the Moon and Mars, lunar polar data analysis, and planetary excavator design and prototype development.

**Gary Cadenhead, Ph.D.** is both an accomplished entrepreneur and educator. He has started and managed his own ventures, consulted new ventures, served on the boards of new businesses, and assisted minority-owned businesses. Currently, Dr. Cadenhead serves on the boards of several start-up ventures, including Halsa Pharmaceuticals, Signal One, and EADevices. During 2004, he served as Chairman of the Board of Schlotzsky's Inc. Dr. Cadenhead is on the advisory board of *The Journal of Private Equity*, is President of the MOOT CORP Foundation, and is Director of the MOOT CORP Pontoon Fund. Until recently, he was a Senior Lecturer in Entrepreneurship and Associate Director of the Kelleher Center for Entrepreneurship in the McCombs School of Business at The University of Texas at Austin. Previous, Dr. Cadenhead held faculty positions at Stanford University, UCLA, and the University of California at Santa Barbara.

**Malcom Carter** is an internationally acclaimed filmmaker and communicator whose work has been seen by over 500 million people in 145 countries. Based in Vancouver, British Columbia, he has been nominated for 16 motion picture awards including Best Documentary, Best Director Documentary, Best Educational Film, and Best Public Service Project. His groundbreaking diabetes documentary was nominated in the International Health And Medical Awards (the "Academy Awards" of medical films) for its life saving and educational impacts. Mr. Carter has a passion to use film, television, the Internet, and other emerging technologies to get people inspired and excited about the next epoch of human civilization – the transition of humanity from Earth to space.

**Hubert P. (“Hu”) Davis, P.E.**, is an aerospace engineer who managed the design and early development of several Apollo spacecraft systems. His entrepreneurial accomplishments include (a) founder of Eagle Engineering, Inc., (b) systems engineering and management support for Conestoga I, the rocket that achieved the first privately funded flight into space, and (c) a business partnership with Apollo astronaut Buzz Aldrin to develop an economical and powerful Fly Back Booster concept patent to enable the re-use of spent booster rocket stages.

**Javier Díaz** is a Research Associate with the NASA Center for Space Resources at the Colorado School of Mines. He specializes in addressing both the technological and economic challenges associated with space exploration, with special emphases on (a) refueling spacecraft in space from materials extracted from the space environment and (b) generating energy in space through the use of unique solar cells.

**Sam Dinkin, Ph.D.**, is an active space commerce entrepreneur. As CEO of SpaceShot, Inc., he is opening space to people of all means through a skill game with space travel prizes. Dr. Dinkin also serves on the advisory boards of the Colony Fund, the Lifeboat Foundation and the Space Settlement Institute and is a Space Advocate in the Space Frontier Foundation. Dr. Dinkin received his Ph.D. in economics from the University of Arizona after studying under Vernon Smith, recipient of the 2002 Nobel Prize in Economics.

**Michael B. (“Mike”) Duke, Ph.D.**, is a planetary scientist with a long-time interest in lunar exploration, the development of space resources, and space solar power. He was a Principal Investigator in the Apollo 11 Lunar Sample Program, and became the Curator of the lunar sample collection at the Johnson Space Center. As Solar System Exploration Division Chief and then Assistant Director for Space Science at the Johnson Space Center, Dr. Duke guided the development of concepts for human exploration of the Moon. Since his retirement from NASA, he conducted research at the Lunar and Planetary Institute in Houston until he was appointed as Director of the Center for Space Resources at the Colorado School of Mines.

**Paul Eckert, Ph.D.**, is the International and Commercial Strategist within the NASA Systems unit of The Boeing Company in Arlington, Virginia. Drawing on his expertise in building international and public-private coalitions, he develops strategies to strengthen business relationships and explore new commercial opportunities. Previously, Dr. Eckert helped promote the growth of the commercial space industry as an official within the U.S. Department of Commerce’s Office of Space Commercialization and within the NASA Office of Legislative Affairs, having been a science and technology advisor to former U.S. Senator John Breaux.

**Burke O. Fort, J.D.**, is a Program Manager of The University of Texas at Austin Center for Space Research, where he is in charge of the business planning and development. Mr. Fort is also

the Executive Director of The Foundation for Space Exploration – a tax-exempt, non-profit philanthropic foundation dedicated to "weaving space into the fabric of everyday life on Earth." He is a recipient of the NASA Public Service Medal; and one of his programs was awarded the prestigious Rotary Stellar National Award for Space Achievement.

**Owen K. Garriott, Ph.D.**, one of the first six NASA Scientist-Astronauts, flew to Skylab twice and at one time held the world space duration record of approximately 60 days, more than double the previous record. After retiring from NASA in 1986, Dr. Garriott has consulted for various aerospace companies, served as a member of several NASA and National Research Council committees, and became Vice President of Space Programs at Teledyne Brown Engineering. Dr. Garriott is a founder of ExtremoZyme, Inc., which develops enzymes from novel microbes, and Alabama Ethanol, Inc., which works on technology leading toward U.S. energy independence.

**James Head, Ph.D.**, is Chief Scientist for Integrated Space Exploration at Raytheon Missile Systems (RMS) in Tucson, Arizona. He serves as Project Scientist on numerous space mission proposals, science team member on Mars Scout proposals, and sponsor of internal RMS space-related efforts. Dr. Head also serves or has served as Robotics Lead, ISRU Lead, and Science Team Lead for Corporate Raytheon's work under the Concept Exploration and Refinement contract to NASA's Exploration Systems Missions Directorate.

**Alex Ignatiev, Ph.D.**, is the Director of the Texas Center for Advanced Materials and Distinguished University Professor of Physics, Chemistry, and Electrical and Computer Engineering at the University of Houston. Dr. Ignatiev has worked in advanced materials in the space environment since he originated the concept of the Wake Shield Facility (WSF), a spacecraft that utilized the vacuum of space for the growth and fabrication of advanced thin film materials and devices for the microelectronics and energy fields. He has also been instrumental in the transfer of technologies to the private sector through the generation of five spin-off companies and six licensed technologies in the past six years from his Center.

**Narayanan M. Komerath, Ph.D.**, is a Professor of Aerospace Engineering at the Georgia Institute of Technology. His research interests range from experimental aerodynamics to the use of tailored force fields for space-based construction. As an educator at Georgia Tech, he leads knowledge integration projects for cross-disciplinary learning, including the use of business planning and aerospace engineering concepts to bring about a "space-based economy."

**Gregg E. Maryniak, J.D.**, is Director of the McDonnell Planetarium at the Saint Louis Science Center. He is also Executive Director of the X-Prize Foundation, sponsor of the \$10 million ANSARI X PRIZE awarded in 2004 to Mojave Aerospace, led by Burt Rutan and Microsoft co-founder Paul Allen, for flying the world's first private spacecraft to the edge of space.

**Mark Nall** is the Manager of NASA's Space Partnership Development Program at the Marshall Space Flight Center. He oversees the work of NASA's 12 Research Partnership Centers, which support joint industry, academia and governmental research efforts leading to commercial development. The recipient of numerous awards, Mr. Nall holds the Air Force Meritorious Service Medal, and was recently inducted into the Space Technology Hall of Fame.

**Thomas C. ("Tom") Taylor** is a Professional Civil Engineer, inventor, entrepreneur and activist in the commercial aerospace industry. He has invented space hardware that has flown on the space shuttle 19 times and has been issued 10 U. S. patents. He has used these inventions to help

start new companies, including Spacehab, Kistler Aerospace and Global Outpost, Inc. Mr. Taylor is presently Vice President of Lunar Transportation Systems, Inc., a company focused on affordable commercial transportation to and from the moon's surface.

**Harvey J. Willenberg, Ph.D.**, has accumulated a 22-year record of leading advanced civil space projects at The Boeing Company, where he has produced important advances in robotic planetary exploration, space power technology, human exploration, microgravity materials processing, and automation and robotics technologies. Most recently, he participated in research involving the hydrogen reduction of illmenite available on the Moon to produce oxygen, metals and silicate slags for use by lunar explorers.

**Gary Yabsley, LL.M.**, is the senior partner in the law firm of Ratcliff and Company in North Vancouver, British Columbia. He has been legal counsel to First Nations in Canada for over three decades and has assisted remote, small communities in developing economic opportunities and meeting unique demands for infrastructure and services. This work has included building cooperative business relations on run-of-the-river power projects, transmission lines and forestry initiatives.

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