Space Systems Workshop June 25-26 Biosphere 2

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Attendees names are in green, other invitees in red

Space Systems Strategic Planning Workshop Flipchart Notes June 26th

Opportunities for new capabilities:

- Extend iPlant to big data assimilation in other application areas
- Rebuild sample analysis capability

Strategic and/or Policy Issues:

- Need policy and resource decisions regarding classified or ITAR research
- Robust infrastructure for large data collection – including security (classified)
- Need to cultivate new PI's and address how they're evaluated
- Need for science analysts (non-tenure)
- Need strategy for "coopetition" with "frenemies" ASU and NASA centers
  - Issue of being frozen out by NASA
- Need institutional support for large proposals
- Need more high-level, strategic relationships with Industry and government
- Beware of risks in teaming with start ups
- Identify iPlant needs plan beyond 10 years

Next Steps:

- Form broad planning group(s) – call it ASL?
  - Articulate value proposition
  - Include Long term vision
  - Identify commonalities
  - Identify services needed – perhaps a shared center called ASL
- Proposed classification for planning groups
  - Planetary
  - Commercial
  - Earth sensing
  - Astrophysics
  - Security

Strategic Planning Workshop

Space Systems

June 25-26, 2015

Frank Lederman

imagination at work

noranda

ALCOA

CRAY
THE SUPERCOMPUTER COMPANY

BLASCH
PRECISION CERAMICS

ARIZONA

PITT

UT DALLAS

CARNEGIE MELLON UNIVERSITY
PITTSBURGH PENNSYLVANIA 1900

ILLINOIS

2

Goals for Day Two

- Breakout sessions for each candidate thrust (2 x 50 min)
- Report-backs to entire group
  - Summarize key results & issues
- Group discussion
- Next steps / action items

Breakout Sessions - Key Topics

- Specific opportunities for growth
  - Who might fund future work?
  - Who are our competitors?
  - What partnerships would help us?
- New strategic capabilities
- Project time horizon / phasing
- Resources required
  - Program-specific
  - Infrastructure
- Other program risks
- Strategic issues

We Need a Strategy to:

- Support the vision and/or strategy of parent organization
- Guide allocation of resources
  - What will grow and what will shrink?
- Show focus
- Inspire objectives that are *required* to achieve the vision
  - Unique, Enabling, Accessible, Sustainable
- Help unify the organization around a common set of goals

Strengths and Weaknesses

- Internal focus – emphasis on competitive capabilities
- What are your core competencies?
  - Transcend several departments or groups
  - Provide true competitive advantage / differentiation
  - Produce a barrier for others to enter
- Examples
  - Unique facilities difficult and/or expensive to duplicate
  - Unique skills, such as a critical mass of talent in one area that took years to establish
  - Local climate / ecology
  - Partnerships / relationships
  - Weaknesses: resource limitations in required areas

What <u>can</u> we do?

Opportunities and Threats

- External focus
- What are the external forces affecting your organization?
  - What changes have you seen and do you envision?
- What are the strategic options to respond?
  - What strategic capabilities are required?
  - Which programs should grow? Which should shrink?
- Examples
  - Evolving model for competing for federal funding
  - New budget constraints
  - Changing demographics for students, legislature, philanthropy, …

What should we do?

Breakout Sessions – Key Topics

- Specific opportunities for growth
  - Who might fund future work?
  - Who are our competitors?
  - What partnerships would help us?
- New strategic capabilities
- Project time horizon / phasing
- Resources required
  - Program-specific
  - Infrastructure
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Breakout Session Locations

- **A: Earth Sensing**
  - — Sonoran Room – Front **Alfred McEwen**
- **B: Mars**
  - — Mojave Room – upstairs **Tim Swindle**
- **C: Infrastructure & Enabling Technologies**
  - — Patagonia Room **Dave Gaylor**
- **D: Space Situational Awareness and Near Earth Object Analysis**
  - — Sonoran Room – Rear **Brian Ten Eyck**
- **E: Habitable Exoplanets / Life Beyond the Solar System**
  - — Office – upstairs **Marcia Rieke**

BREAKOUT SESSION A: EARTH REMOTE SENSING

Title: Earth Sensing

Themes:

1. **Sensing everywhere, molecular to global scales.**
2. **Assimilation of big data to actionable knowledge on relevant timescales (minutes to days)**
3. **Cultivation/hiring of PIs**

1. Time horizon

- years to decades
- influence new Earth decadal survey?
- When/if to invest in a startup firm?

2.   Specific opportunities for future external funding

- NASA (Earth Ventures, etc.)
  - Problem: lack of PI candidates
- Defense-related (food security as an example)
- Commercial (NorthStar as an example)

3. Who are our competitors?

- Other universities, NASA centers, JPL, APL
- ASU is being much more aggressive than UA about hiring candidate flight PIs and submitting major proposals

What is our competitive advantage?

- Science

- Instrument development (in Astronomy, LPL, Optical sciences, but not in Earth sciences departments)

- Biosphere-2, LEO, to derive data products and algorithms to apply to remote sensing
  - Biosphere2: completely controlled environment including isolated energy. Optimal for complete sensing and control. Diverse ecosystems.

- iPlant…growing into iEverything, big data assimilation to knowledge

4. New strategic capabilities

- Enhance big data capabilites
- Cluster hiring of good scientists who also are potential PIs of large projects
- Sensing at all levels—ground, air, and space
- More high-level strategic insight with industry (Raytheon, LMA) and government
    - Embed UA people

5. With whom should we partner?

- Many possibilities, depends on specific opportunities.

- Astronomy and LPL have track records with JPL, GSFC, APL, LMA, Ball Aerospace, Teledyne, KinetXs, SDL, many Universities.

- Partnering with a startup is a new experience for some of us

6. Resources required
Program-specific

- Strategic hires in Earth science, people who are candidate future PIs of large projects

- Task force to coordinate between many diverse units across campus
    - Geosci., atmosph. Sci,, LPL, astronomy, Optical Sci., iPlant, Natural Resources & Environment, Bio-2, engineering, computer sci., etc.
    - How to cooperate with industry such as NorthStar

- One small example: B2 Landscape Evolution Observatory (LEO) hyperspectral is 400-1000 nm. Need to extend to 2500 nm to connect to remote sensing. Great future potential from hyperspectral sensing, but vegetation is complicated and Bio-2 can simulate many environments, a unique advantage to UA.

Infrastructure

- Lots of good infrastructure exists at UA, key issue is connecting people and organizations.
    - Recommendation: Task force on Earth sensing

- Good instrumentation capability in astronomy, Optical sciences, and LPL.

- Lots of Earth science capability

- Big data—greater capability needed for many opportunities

7. Other program risks/weaknesses

- Leaders/PIs for big Earth sciences projects
  - University hiring/promotion policies (P&T if you're working on a big project you're at a disadvantage), might be a 10 year long process and if you don't have tenure that's a large apparent gap in productivity
- Long-term productive relationships with industry at a strategic "high" level
- 20 year vision: replicate the approach of astronomy
  - For federal funding
  - For commercial applications
- Long-term knowledge of what NASA and other funding agencies want for big ($30M+) projects

8. Strategic issues

- Hiring potential PIs
- Making the right connections across campus
- Embedding/Interning UA people in agencies, companies

- Looking forward to future sensing technologies
  - Wind sensing at different angles
  - Active RADAR, LIDAR

- Grand Challenge: Full monitoring of BS2
    - How to get Biosphere2 completely off the grid
    - How to do all internal/external sensing, data management, knowledge synthesis, decision making

- What are our business opportunities?
    - Development as a service: e.g., hardware
    - Prototyping, scaling manufacturing, long term service support (hardware and analytics)
    - Software as a service: e.g., algorithms
    - Science as a service: e.g., discovery

"Remote sensing science knowledge center"

◦ Consulting work: contract work to solve a specific problem

◦ Workforce development: contracts to fund students/postdocs to work on company problems

◦ Warning about startup companies like NorthStar—don't put too much reliance on them until more secure

Breakout Participants: Alfred McEwen plus

#1 Brian Liesveld, Neal Armstrong, Mike Lessor, Eric Lyons, Xubin Xeng, Kim Patten, Richard Snodgrass, Peter Troch
#2 George Reike, Doug Hockstead, John Kececioglu, Brian Liesveld, Tom Zega, Tom Koch, Jon Pelletier, Kim Patten

BREAKOUT SESSION B: MARS

Title: Mars and Mars Sample Return

The highest priority in the Decadal Survey for Planetary Sciences for 2013-2022 is "taking the first critical steps toward returning carefully selected samples from the surface of Mars." The pace toward sample return has slowed as a result of budget cuts, but Mars sample return is likely to be a high NASA priority for at least the next decade. The webpage for NASA's Mars Exploration Program talks of bringing samples back "early in the next decade" (http://mars.jpl.nasa.gov/technology/samplereturn/), but since the Mars 2020 mission is a precursor to sample return, the timescale is more likely to be the end of the 2020s. At that point, there will be samples to be analyzed. However, there are likely to continue to be precursor missions in support of the long-term goal, with at least one precursor launching in each launch window (Mars launch windows are two years apart, and the missions are defined through the 2020 launch window).

1. Time horizon

The idea is to position UA to be a leader in Mars science in the 2020s, as we have been throughout the planetary exploration age.

10-20 years to Mars sample return (site selection a little earlier); Opportunities for Mars missions or instruments on Mars missions likely to occur regularly (next launch that is not committed is 2022, if there are investigator-led instruments, those would need to be competed very soon); 6 years to Mars 2020 data

Other sample return missions: 8 years to OSIRIS-REx return; lunar sample return within 10-15 years; comet sample return 15 years

2. Specific opportunities for future external funding

UA has a long history of Mars exploration. In the last 20 years, that has included the instrument PIs for the IMP (Imager for Mars Pathfinder), the Mars Odyssey Gamma Ray Spectrometer, the TEGA (Thermal Evolved Gas Analyzer) on the Phoenix Mars Lander, and HiRISE (High Resolution Imaging Science Experiment) on Mars Reconnaissance Orbiter. In addition, UA's Peter Smith was mission PI for the Phoenix Mars Lander. Opportunities to lead instruments and missions are likely to continue. In addition, if and when samples are returned, the returned samples will be a source of significant funding for sample scientists. Although the total amount of funding for sample science is likely to be smaller than for instruments, it can support a significant number of scientists and students, and it is worth noting that the PIs for NASA's last three sample return missions, STARDUST (comet), Genesis (solar wind), and OSIRIS-REx (near-Earth asteroid), have all been sample scientists.

3. Who are our competitors?

For instruments, JPL, APL, SWRI, ASU, and the University of Colorado.

For analysis of returned samples, NASA-JSC, NASA-Ames, UCLA, Chicago, NRL/Carnegie/Smithsonian, ASU, University of New Mexico

What is our competitive advantage?

Primarily, our history of successful Mars instruments and missions, and our strength in Mars remote sensing and the study of Mars surface processes. We have some top-notch sample analysts; they can be a strength if our Mars program is integrated better.

We've have been managing OSIRIS-REx, which gives us credibility in managing even larger missions. OSIRIS-REx also provides a logical opportunity to add to our analytical capabilities. The better-prepared we are for OSIRIS-REx, the better prepared we will be for Mars samples.

The Biosphere 2 LEO project (or other similar projects at Biosphere 2) could provide a unique opportunity for studying weathering processes on Mars, although it has not been applied to that.

4. New strategic capabilities

To be at the cutting edge for sample return analysis, there are techniques UA has never had that will be crucial for Mars samples, including organic geochemistry (an organic geochemist has just been hired in Geosciences, who may or may not be interested in Mars problems) and high spatial resolution isotopic analysis.

One capability that we could develop is swarms or constellations of cubesats or mini-sats. These could be used for anything from atmospheric studies to missions where high spatial resolution is achieved by operating cubesats closer to the surface (therefore deeper in the atmosphere) than a full-sized satellite would be risked to atmospheric sample return (if a way to safely return a cubesat through Earth's atmosphere can be devised. UA is not a leader in cubesat technology, but to date cubesats have largely been used as student demonstration projects – we could skip that step and attack a more difficult problem than has been attempted.

There are potentially valuable near-surface geophysical techniques (such as ground-penetrating radar and electrical resistivity) for which UA has expertise, but has never tried to develop an instrument for a Mars rover.

5. With whom should we partner?

We have begun partnering with Raytheon Missile Systems on cubesats. That is a partnership that could be developed further. To develop instruments, we will need to work with our traditional aerospace partners, such as Ball and Lockheed-Martin, and the laboratories and NASA facilities we have partnered with, potentially including JPL, APL, NASA-Ames, and NASA-Goddard.

An intriguing possibility that was suggested at the retreat was to find a way to partner with ASU, at the expense of the NASA centers.

6. Resources required

Program-specific

Increased coordination among groups and individuals working on Mars is needed. The question is how to facilitate that.

We need to find ways to identify new instrument PIs. Do we look among the faculty we have and try to groom them to become instrument PIs, or do we need to go look for more instrumentation-oriented faculty (e.g., someone with experience as a science lead on HiRISE)?

We need to add faculty who are sample analysts who will be active on the timescale of potential Mars sample return in 15-20 years. Obvious disciplines include: Organist geochemistry (Jess Tierney has just been hired – she may be the person, or she may be able to help identify the person); Spatially resolved isotopic analysis (SIMS – an issue here will be that ASU's established expertise may make it difficult for UA to get funding to break into the field); Experimental petrology (UA was extremely strong in this 10 years ago, but Jiba Ganguly has retired, Mike Drake passed away, and Dante Lauretta has shifted his focus to OSIRIS-Rex).

Infrastructure

If we are going to try to develop cubesat missions, there would be infrastructure associated with that.

Some of the sample analysis techniques will require infrastructure, such as a SIMS (Secondary Ionization Mass Spectrometer). However, some of the sample analysis techniques would require minimal infrastructure investment (e.g., between Geosciences and LPL, there is a significant amount of experimental petrology infrastructure).

7. Other program risks

Mars sample return has been ~10 years away for more than 40 years. A strategy devoted solely to Mars sample return is dangerous. However, there will be other sample return missions (starting with OSIRIS-REx), and there will be other Mars mission opportunities.

There is really only one customer, NASA. Even if we are selected for instruments on missions flown by other agencies, the funding comes from NASA. We have already had one case where we won the competition for an instrument on an ESA mission, but NASA later reduced its financial involvement by cutting off funding for instruments like ours.

Sample return science tends to be costly for startup, but to support only individual investigators or groups. Thus sample return science is unlikely to provide large amounts of grant money in and of itself, although it does train students, and sample analysts often become instrument PIs.

8. Strategic issues

ASU has made a significant investment in planetary instrumentation capabilities in the last five years. They are now a significant player in the field, the only university other than Colorado with capabilities rivaling ours.

9. Potential members of a steering committee or strategic planning group:

Alfred McEwen (LPL), the only UA person leading a Mars instrument at the moment;

Bill Boynton (LPL), PI for two successful Mars instruments (and at least two on missions that failed), and a former sample analyst;

Dante Lauretta (LPL), PI for OSIRIS-REx and a sample analyst;

Tom Zega (LPL), junior faculty member who is a sample analyst;

Jess Tierney (Geosciences), newly hired organic geochemist, who can advise on directions to go, if she is not interested in analyzing Mars samples;

Pete Reiners (Geosciences), department head and a sample analyst;

Walt Harris (LPL), mid-career instrumentation-oriented faculty member who is interested in cubesats;

Dave Gaylor (AME), interested in developing cubesat applications at UA

Roberto Furfaro (SIE), the only Engineering faculty member involved with OSIRIS-REx, and someone who will have ideas for contributions that Engineering can make;

Peter Troch (Biosphere 2), if we want to talk about ways to leverage Biosphere 2;

Jon Pelletier (Geosciences/LPL), an expert in Mars surface processes, also has connections to both LPL and Geosciences (as well as being a part of the LEO project);

Bob Downs (Geosciences), the only UA scientist involved with Curiosity;

Christopher Hamilton (LPL), junior faculty member who studies Mars surface processes, and would have ideas about directions Mars research could take;

Shane Byrne (LPL), mid-career faculty member who studies Mars surface processes, has been Co-I on some instrumentation proposals.

BREAKOUT SESSION C: INFRASTRUCTURE AND ENABLING TECHNOLOGIES

Key Enabling Technologies and Infrastructure:

It's all about communication!

1. How to get data back from our space missions?
    a. We have people in ECE that can help!
    b. We should be investing in technologies such as laser comm
2. How can we improve our communication with each other?
    a. Establish an organization of interested people (Arizona Space Lab)
    b. Collocation
    c. Centralized cyberinfrastructure
    d. Colloquia, workshops
    e. Start collaborating on small pilot projects
3. How can we do our communication in a secure manner?
    a. Centralized cyberinfrastructure to handle controlled data
    b. Central facility that is dedicated to ITAR/EAR work

Session 1: Nirav Merchant, Gene Giacomelli, Marwan Krunz, Daewook Kim, Chris Walker, George Rieke, Buell Jannuzi

Session 2: Jeff Kingsley, Justin Walker, Xubin Zeng, Eric Lyons

1. Technologies to Enable Next Generation Space Mission
    a. We have advantages in systems in a range of frequencies: optics, sensors
    b. Electronics fabrication – small custom jobs are not supported by industry (George), similar to setup to Mike Lesser's shop, could be part of a larger core support facility. OSC/SO has this capability (Jeff)
    c. Pico meter level sensing and control (Daewook)
2. Enabling Relationships/Partnerships

3. Needs of Space Agencies

    a. Spectrum Management, communication technologies, laser communications
        i. Telecom bandwidth availability, getting the data back. (Chris)
        ii. Cognitive radios, challenges getting NSF funding so could use seed funding
    b. Lightweight space optics, how to align with accuracy (Daewook)

4. Physical Infrastructure
    a. Steward needs new space so we should coordinate to make it applicable to development
    b. Need space for large projects,
    c. Need a place to work on ITAR/EAR, classified projects (should be a priority for DSRI)
    d. Need thermal vac, anechoic chamber, clean room, high bays to increase TRL of our systems – have to base testing in CA – forces us to partner with organizations we might not want to. Hard to work with Raytheon on this due to ITAR, classification issues
    e. How to maintain current unique infrastructure?
5. Organizational Infrastructure
    a. Having facilities like Mike's supported by engineering departments
    b. Arizona Space Lab (ASL) comparable to APL, JPL. But need to keep connection to the academic side. It could house program management, business dev, system development. How to integrate and coordinate efforts? Frequent colloquia. Can start with small pilot projects. Need collocation to foster collaboration. Have to keep it low overhead. Should start with a list of projects that cannot happen without it.
6. Computational Infrastructure
    a. Slick(?) can transcribe voice/text that could help enable searching of symposium presentations (Eric)
    b. Existing capabilities/projects: iPlant, El Gato, Research Computing Center (UITS), … need support to be sustainable
    c. Cyberinfrastructure, cybersecurity, data storage. Gain economies of scale from centralized infrastructure.
    d. No centralized solution for new UITS data protocol so we have to do it locally which causes cybersecurity issues. No way to transfer controlled data on campus.
7. Issues
    a. How to sustain Mike Lesser's shop?
    b. Common central infrastructures need to have enough demand, well managed and supported
    c. Creation and support of pilot projects, example would be how to leverage LSST into SSA, other space related projects
    d. How to find the right expertise from other departments? Existing information is hard to find and gets stale quickly
    e. How do we find out what our capabilities are?
    f. How to form teams to propose? How to connect to the right expertise for the proposal, especially for new faculty? Need a matchmaking service
    g. How to make support engineers more widely available, facilitate transfers within the university
    h. Work force development that is tuned to support our needs. Example: iPlant is losing expertise and cannot replace.
    i. How to keep from losing good support personnel? Common pools can help but how does this work with RCM?
    j. What is the return on investment for our current infrastructure?

BREAKOUT SESSION D: SPACE SITUATIONAL AWARENESS

Space Situational Awareness and Near Earth Object Detection

Space Systems Working Group Breakout Sessions
June 26, 2015

A Definition*

Space debris mitigation and removal

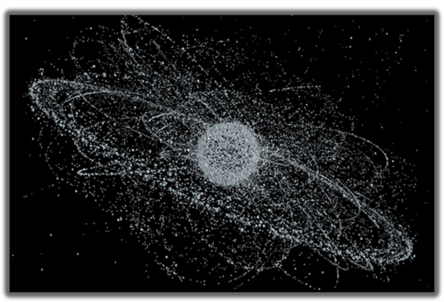
Space traffic management

Space mission assurance

Military space dominance

Space Situational Awareness

The term Space Situational Awareness (SSA) refers to the ability to view, understand, and predict the physical location of natural and manmade objects in orbit around the Earth, with the objective of avoiding collisions.



* According to the Space Foundation

The Opportunity for UA

> "The largest demand from the astrodynamics community [is] the availability of relevant data and algorithms for S&T development and maturation."
> - Moriba Jah, SSA Mission Lead, AFRL/SV

There is a requirement for:

1) trusted, weighted
2) data acquisition and aggregation
3) in real time, and
4) an ability to convert it into actionable intelligence

The Timeline: Now

> "Space must now be considered a contested operational domain in ways that we haven't had to think about in the past."
> - Deputy Defense Secretary Bob Work , June 23, 2015

- DOD is currently performing a strategic review on space to figure out how much it needs to invest, though the Pentagon's FY-16 budget request already includes a $5 billion increase in space security spending over the previous year.
- AFSPC Long Term S&T Challenge (Feb15): "Develop advanced space technologies that provide real-time domain awareness, predictive battlespace awareness … and rapid development and assessment of mitigative COAs."
- According to NASA, more than 500,000 pieces of debris orbit the Earth—including more than 21,000 pieces larger than a softball that are tracked.

UA’s Competitive Advantage

UA has, and creates, expertise and infrastructure directly related to SSA needs:
- Interdisciplinary breadth
- Imaging capabilities (*and data!*) that radar can’t match
- Operations experience

- We can do this for relatively low cost: assets already in place
- More small telescopes already in place that can be tasked and/or repurposed/reinstrumented to focus on SSA
- Very good at hardware (detectors), very good at cyberinfrastructure, data management, and massive data extraction and analysis
- UA is generally strong in observation and measurement science

Specific Opportunities for Future Funding

1. AFRL CRADA
2. In Progress on campus
   - Design and create a Robotic Telescope Network
   - Design and create an “iSSA” capability to address SSA data needs
3. DARPA:
   - Passive, Sparse Aperture Imaging for Space Domain Awareness RFI (by July 3)
   - Hallmark
4. The Minor Planet Center possibly up for bid in 1-2 years (turn astrometry data into orbits)
5. Space-based asteroid search mission (NASA Discovery proposal)—but also an on-orbit SSA sensor (suite)
6. Wayfarer … deploying microsats into lunar halo parking orbits that could be tasked from orbit to go investigate specific objects or events within 1 AU (comets, NEOs) (also, use to establish guide stars for NEO/exoplanet detection) (also heliophysics and space weather monitoring, possibly from high latitude orbits)
7. NSF/NNSA space defense system

- ANTARES: rapid identification of objects / events in LSST that are tagged and shared with other assets for follow-up (big data, algorithm design); extract focused / specialized data streams capturing NEO imagery
- Create a telescope (sensor) network for more selective follow-up tasking (core systems coordination problem: is the robotic telescope network a JCTD candidate?)

Potential Partners / Customers

Established relationships:
- AFRL
- Intelsat
- Lockheed Martin
- NASA

Still to Approach:
- JSpOC
- NASIC
- NRO
- Sandia's Monitoring Systems Center

Future considerations:
- Space-based partner for on-orbit SSA

Strategic Issues

Program Risks
- Consistent / predictable access to telescopic data that does not compromise the core scientific missions
- NEO detection vs SSA … significant overlap in terms of technologies, but to do one very well, the other becomes compromised, inefficient

Considerations
- UA's interest in expanding its 'big data' capabilities beyond iPlant, SOCCOM, and other similar initiatives
- UA's ability to participate in classified projects and handle classified information
- UA's willingness to employ "science analysts" and other technical support staff (a la iPlant and Steward's ETS) who are not tenure-track faculty
- Installing, running, maintaining this infrastructure needs an ongoing revenue stream (and business model)—not just hopping from one award to the next … but it can't just be left to PI's to write successful business plans

Resources Required

Program-Specific

- Need to distill a focused vision with a specific (near term) timeline … **formal internal steering committee** to do this
- Establish and maintain a coordinated voice to customers / partners representing institutional resources and capabilities … this suggests bringing on an **SSA expert** tasked with mapping out a vision, plan, approach, timeline, etc., who is selling the vision
- **SSA Event Ecosystem**: Formal pathway from LSST to other networked resources that are either dedicated or able to be ad hoc retasked; this includes a team just mining LSST data

(Business) Infrastructure

- Robotic telescope networks exist; need **robust infrastructure and expertise** to focus assets and on-demand data collection on SSA/NEO (one advantage of roboticizing is the assets become interruptable)
- **Classified** work: facility and support infrastructure
- Putting real proposals of this scale and complexity together will require institutional support: program management, systems engineers, budgeting … **focused proposal team(s)**

BREAKOUT SESSION E: HABITABLE EXOPLANETS

Habitable Planets & Life Beyond the Solar System

Session 1: Jared Males, Ryan Gutenkunst, Ted Weinert, Ann McGuigan
Session 2: Dae Wook Kim, Gene Giacomelli

1. Time horizon

Want to influence the next astronomy decadal survey that will be released in ~2020. Need to start now but with the knowledge that real proposals won't be needed until after 2020.

Session 1: If we are to influence technologies, need to be starting our technology development efforts now to have demonstrations by early 2018.

2. Specific opportunities for future external funding

Session 1: Largely NASA, biology component right now is largely NSF
But look at comment at end: Could non-NASA funds be found?
Session 2: Likely centered on NASA, NSF for the biology side that might be applicable here – may be study of exo-planets could shed light on Earth's status

NASA Astrophysics has started looking at mission candidates for the 2020 Decadal Survey:

- Far-IR Surveyor – Visionary Roadmap
- Gravitational Wave Surveyor – 2010 Decadal Survey and Visionary Roadmap; to be implemented as US contribution to ESA L3 mission
- Habitable-Exoplanet Imaging Mission – 2010 Decadal Survey
- UV/Optical/IR Surveyor – 2010 Decadal Survey and Visionary Roadmap; science case assumes successful JWST and WFIRST missions
- X-ray Surveyor – Visionary Roadmap; science case assumes successful ESA Athena (2010 Decadal Survey) mission

3. Who are our competitors?

Session 1:
CalTech, JPL, Stanford, STScI, NASA Ames (note that both JPL and Ames are also potential collaborators)
University of Colorado as an astrobiology center [check recent NASA selection of NASA Astrobiology Institute, look at NASA Astrobiology Roadmap]
We are unaware of European space coronagraph efforts
Session 2:
Large observatories (eg. CalTech) all have AO systems
JPL, NASA Ames (they may also be collaborators)

What is our competitive advantage?
Session 1: In addition to astronomy & planetary science, we have world class geosciences and ecology and evolutionary biology

Leverage LPL's experience in mission capabilities

Look at iPlant and other Big Data work and how that would impact data handling, exo-planet atmosphere modeling

UA can produce the highest quality optics – some companies could also do this but techniques are usually proprietary
Coupling optics capabilities with our exo-planet expertise is a unique combination

- **Who works in this area at UA right now?**

Phil Hinz – SO
Laird Close – SO
Daniel Apai – SO/LPL
John Codona – SO
Josh Eisner – SO
Olivier Guyon – SO/OpSci
Michael Hart – SO
Kaitlin Kratter – SO
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Hao Yang – SO
Gilda Ballester – LPL
Travis Barmen – LPL
Caitlin Griffith – LPL
Ilaria Pascucci – LPL
Adam Showman – LPL
Roger Yelle – LPL
Ian Crossfield – LPL
Isamu Matsuyama –LPL
Renu Malhotra - LPL

List does not include people mainly interested in astrobiology. List includes people broadly interested in exoplanets and planetary atmospheres and includes some theorists as well as instrumentalists. Some of these people are post-docs.

4. New strategic capabilities

Session 1: Need to understand how biological processes might influence exo-planet atmospheres: how to design a spectroscopic experiment to distinguish between geological change and biological change
Does Biosphere provide a unique testbed for looking at microbe-driven atmospheric changes?

High contrast imaging testbed, especially a vacuum testbed where we could build it more quickly and cheaply, would need location

Session 2:
From the science perspective, what are the real performance levels required of such a mission to be interesting – is picometer accuracy required, what size telescope, what wavelength range?

5. With whom should we partner?

Session 1: JPL, Ames are possibilities, likely need an aerospace company for ultimate mission competition

6. Resources required

Program-specific

Session 1:

Large item would be the high contrast imaging test bed

Need an astrobiology experimenter

Need to look at how to develop PIs would can lead large NASA projects w/o compromising their career trajectories [eg. more inclusive success criteria, teaching relief, development of other measures of success]

Session 2: Optical Sciences would be a natural partner in developing the test bed

Infrastructure

7. Other program risks

Session 1: On the biology side, new people that may be needed span several departments so how do we get them excited about astrobiologists but also other interdisciplinary hires [sociology side of cluster hires]

If an exoplanet mission isn't ranked highly in the next decadal survey, NASA won't fund it

Test bed would be coupled with a notional telescope design and might not match what NASA selects [suggests building in a degree of flexibility built in]

8. Strategic issues

Session 1: Any hope for doing this outside of NASA? Would SpaceX, for example, be a place to start?

Session 2: Even if NASA funding is uncertain, existing assets such as the Large Binocular Telescope and Magellan telescopes will permit continued progress in characterizing planets and allow technology demonstrations

To "sell" a project on this scale, need to recognize the societal benefits and implications, need help on how to do this effectively

Session 1 Suggestions:

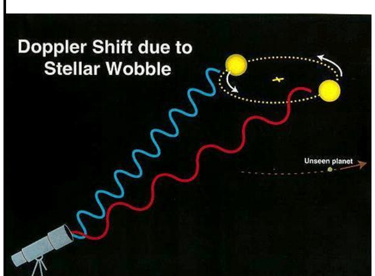
1) Biologists should invite astrobiologists to give colloquia

Habitable Planets & Life Beyond the Solar System

June 26, 2015

1

How to Find Planets Around Other Stars



Nomenclature:
Star: either has or is burning H in its core, $M > .08M_{sun} = 80M_{Jupiter}$
Brown Dwarf: large enough to burn H2 briefly, may form as a free floating object in space by contraction of a small cloud, $10M_{Jupiter} < M < 80M_{Jupiter}$
Planet: formed by accretion around a star, $M < 10M_{Jupiter}$
Recall :
$M_{Sun} = 1000\ M_{Jupiter}$ $1\ M_{Jupiter} = 318\ M_{Earth}$

- By direct imaging – take a picture and see one!
  - Hard because planets are dim
- By looking for varying Doppler shifts in a star's spectrum
  - Relatively easy
- By looking for varying light output from a star due to transits ("eclipses") by a planet
  - Not as easy as Doppler shifts but can yield more information
- By looking for variations in a star's position
  - Very hard, mostly superceded by Doppler shifts
- By looking for gravitational lensing events
  - Relatively easy but yields only statistical information about planets

2

Getting Ahead of the Curve

- Need to look at NRC Decadal Surveys and Mid-Decade Assessments
  - provide guidance on what the community thinks is highest priority for the next 10 years which in turn guides NASA
  - Surveys produced for each of the SMD areas (astrophysics, planetary, heliophysics, earth sciences)
  - See http://www7.nationalacademies.org/ssb/

3

Future Astrophysics Missions

- WFIRST almost ready to start construction with our opportunities in the science areas and with synergies with LSST
- NASA Astrophysics has started looking at mission candidates for the 2020 Decadal Survey:

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List from NASA Astrophysics White paper at http://science.nasa.gov/astrophysics/documents/

4

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2. Specific opportunities for future external funding

Likely centered on NASA, NSF for the biology side that might be applicable here – may be study of exo-planets could shed light on Earth's status

Could non-NASA funds be found?

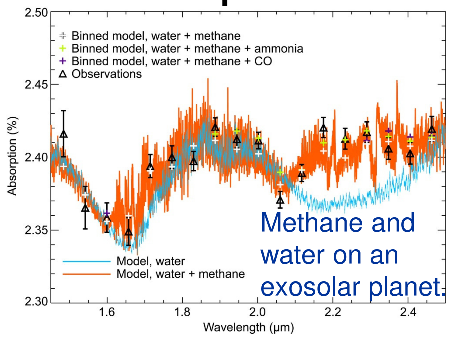
5

What agencies/industry is interested in funding this work, and what programs/funding levels do they have?

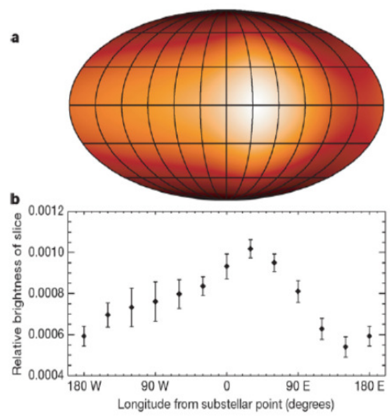
- NASA will fund this mission, which will likely cost more than $1B if the mission is highly ranked in the 2020 decadal survey
- We need to work with the NASA-sponsored ExoPAG (Exoplanet Exploration Program Analysis Group) to ensure a mission formulation that matches our interests. Danial Apai is currently a member.
- See https://exep.jpl.nasa.gov/exopag/decadal/

6

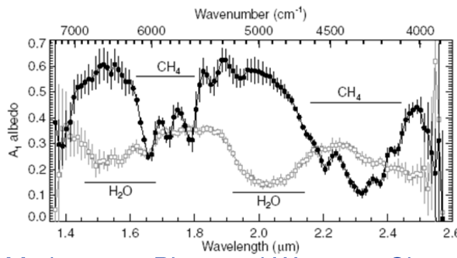
Exoplanet Characterization



Methane and water on an exosolar planet.



Surface temperatures on an exosolar planet from Spitzer data.



Methane on Pluto and Water on Charon.

Detailed comparisons to Solar System objects are becoming feasible!

7

Who are our competitors?

Rather than asking “Who is our competition” we need to ensure that we are allowed to compete:

The next large astrophysics mission, WFIRST, will be built entirely within NASA Centers (Goddard & JPL) with no chance for university groups to compete for any of the construction.

There are similar concerns in other NASA areas including Planetary Sciences.

- **CalTech, JPL, Stanford, STScI, NASA Ames**
- **(note that both JPL and Ames are also potential collaborators)**
- **University of Colorado as an astrobiology center [check recent NASA selection of NASA Astrobiology Institute, look at NASA Astrobiology Roadmap]**
- **Large observatories (eg. CalTech) all have AO systems**
- **We are unaware of European space coronagraph efforts**

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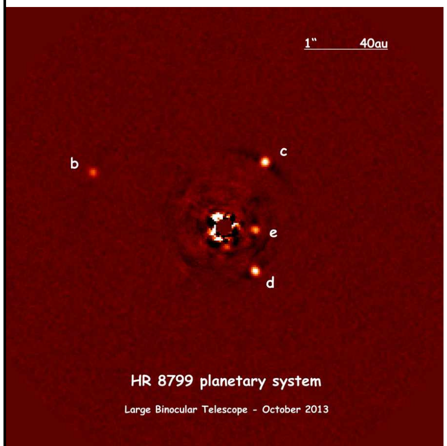
What is our competitive advantage?



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Future Exoplanet Mission

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10

What facilities/equipment do we have and what do we need?

- High contrast imaging testbed, especially a vacuum testbed where we could build it more quickly and cheaply
- Need to understand how biological processes might influence exo-planet atmospheres: how to design a spectroscopic experiment to distinguish between geological change and biological change
- Does Biosphere provide a unique testbed for looking at microbe-driven atmospheric changes?
- Should continue development of collaborations with JPL and NASA-Ames
- In the short run may need to provide misc. travel funds and other support for people to attend meetings and visit aerospace companies and other potential collaborators
- Eventually will need funding for proposal prep

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Benefiting from Our Investments

- LBTI (Large Binocular Telescope Interferometer) is a major instrumental development largely funded by NASA
  - Is entering science verification phase to be followed by a program to identify ideal stars for exoplanet imaging searches
- There may be similar future opportunities
  - For example, groundbased follow up for TESS, e.g., by spectroscopic observations of planet transits
  - TESS is the Transiting Exoplanet Survey Satellite, due to be launched in 2017, which will identify bright stars with transiting planets

12

What are UA's competitive advantages and weaknesses for a major Exoplanet mission?

- Strengths include
  - broad range of expertise
  - people with NASA mission experience
  - ground based telescope support and synergy
  - EXCEDE is under technology development for a possible NASA Explorer (PI Glenn Schneider)
- Weaknesses
  - need to identify a leader
  - need more participation from biologists
  - can't do a mission of this scale entirely ourselves and will need to team with an aerospace company and/or NASA center

Strategic Issues and Risks

- Don't want to be frozen out as has happened with WFIRST
- If proposed mission is not ranked highly enough in the 2020 Decadal Survey, then real work and funding will be postponed until many years in the future
- Want a mission architecture that plays to our technical strengths
- How do we address the "Life Beyond the Solar System" part of this theme: Need to understand how biological processes might influence exo-planet atmospheres: how to design a spectroscopic experiment to distinguish between geological change and biological change
  - Need an astrobiology experimenter
  - Does Biosphere provide a unique testbed for looking at microbe-driven atmospheric changes?