

LUVOIR 4th Face-to-Face STDT Meeting

JPL, Pasadena CA

April 17 - 18, 2017

Talk slides available at <http://asd.gsfc.nasa.gov/luvoir/events/>

Table of Contents

High-Level Meeting Summary	1
Day 1 (Monday April 17)	1
Day 2 (Tuesday April 18)	3
Detailed Minutes	4
Day 1 (Monday April 17)	4
Matt Bolcar: LUVOIR Update on Architecture A Design Process	8
Aki Roberge: Intro to Outlining the Interim Report	16
Exoplanet Breakout Session	25
Cosmic Origins Breakout Session	32
Technology Breakout Session	33
Post-Breakout Reports	34
Day 2 (Tuesday April 18)	42
Communications Discussion.....	43
Exoplanets Breakout Session	53
Cosmic Origins Breakout Session	58
Technology Breakout Session	58

High-Level Meeting Summary

Day 1 (Monday April 17)

We kicked off with welcomes from David Gallagher, JPL Associate Laboratory Director for Strategic Integration and the STDT chairs. We then had about ½ hour of discussion on general concerns (details below). There seem to be some misconceptions in the community about the LUVOIR / HabEx relationship, in both directions (teams are merging, teams are in conflict). Neither extremes are true; working relationship w/ HabEx is good. The LUVOIR and HabEx leadership teams have monthly tag-up telecons. We will start providing regular updates on those discussions at the **LUVOIR STDT telecons, which will go back to weekly starting May 2**. There was a general request for more STDT participation in the pre-work for the instrument design runs, which should happen through the instrument teams. Some STDT members thought it's already decided that LUVOIR Architecture B will be less technologically ambitious than Architecture A. This is a STDT decision that hasn't happened yet (will be discussed starting late-summer / fall 2017).

Reviews	Month of Oct	Senior advisors, Aerospace Corp, GSFC red team
Deliver complete “reviewer’s draft”	Oct 1, 2017	
STDT review of whole report	Mid Sept?	At STDT meeting #6
Finalize complete “reviewer’s draft”	Month of Sept	Make it complete and uniform
Individual writing assignments due	Mid Aug	
Assess report progress	July?	At STDT meeting #5 (joint w/ HabEx)
Writing!	3.5 months	
Finalize report outline	Late April	Start at STDT meeting #4

Day 2 (Tuesday April 18)

We started the day with a wide-ranging discussion of LUVOIR communications. First Shawn Domagal-Goldman showed a draft of a joint LUVOIR/HabEx slide with statements on cost (in a nutshell, “we don’t know yet what these missions cost, but will find out”). The slide will be edited slightly, sent to the LUVOIR STDT, and coordinated with the HabEx team. Once final, it will be incorporated into the standard LUVOIR slide decks.

There is a feeling that we need to up our game on getting the word out to the community. In the Communication folder within the Google Drive, there are spreadsheets for “Conference Schedule” and “Colloquia and Seminars”. Up until now, these have been largely used to record what we’ve done. Now we need to plan more strategically, identify places we should talk, and identify speakers.

We also discussed the need for 1) a standard slide deck with a COR focus and 2) a technology slide deck. Marc Postman will adapt his talk from the HST/JWST 5 meeting in Venice for the COR deck. Matt Bolcar will lead development of a technology slide deck. We also discussed better promotion of WFIRST coronagraph development milestones (a major one was achieved recently).

There will be a big splash for the Decadal Studies at the Jan 2018 AAS meeting. We discussed ideas for what activities we want to do.

1. Special Session of LUVVOIR talks. Not only STDT members. Session proposal due May 25.
2. Splinter meeting for hands-on work with tools (like last AAS).
3. One whole table (or two) for the Decadal Studies at the NASA booth (instead of split between COR and EXO tables like last AAS).
4. Tools demos on huge touch screen at STScI booth (like last AAS).
5. "Ask me about LUVVOIR" buttons. We'll have to pay for these ourselves (NASA swag rules).

In the interests of better and more complete communication with the whole team, we've decided to go back to weekly STDT telecons (will be canceled if there's no need to talk in a particular week). At these telecons, we'll start having a more standardized agenda, with regular updates on HabEx interactions/discussions.

The team then went into breakout sessions again for additional work on various topics (polishing report outline, planning observation scenarios, technology trades, etc.). The team achieved the desired meeting deliverable of a draft Interim Report outline. This will be collected together and polished by the end of April, then sent to the whole STDT. The meeting ended at noon with group photos. After lunch, some of the team went on fantastic tours of the Starshade Lab, the High-Contrast Imaging Testbed, the Mars Yard, and the Space Flight Operations Facility.

Detailed Minutes

Courtesy of Giada Arney

Day 1 (Monday April 17)

David Gallagher (JPL): Welcoming remarks. Thank you for traveling out here.

Debra Fischer: Welcome to our F2F meeting. Things getting serious now. Looking forward to results of IDL studies. Planning on outlining the interim report.

Brad Peterson: The work starts now. Let's go around and have everyone introduce themselves.

(introductions)

Debra: At place we're at, nothing is finalized.

Brad: From community we hear a lot of things. LUVVOIR used to be assembled in space. LUVVOIR and HabEx have merged. LUVVOIR is going to be 100 billion dollars. (jokes) None true we have been working on mission architectures have not made any choices yet. This is a process and not

done until we say it's done. Try to dispel rumors especially ones that attach a dollar value to LUVOIR.

Debra: Aki or Julie can comment on IDLs and they have defined instrument in some way. What does that mean in terms of locking on?

Aki Roberge: I wanted to comment on point about cost. Everyone gets this question when giving LUVOIR talks. We should generate another joint slide (HabEx and LUVOIR) about what to say when asked about cost. Hoping to show in communications tomorrow. See what team thinks about language. That's about the cost issue. About the significance of IDL runs. Interesting question. Julie?

Julie Crooke: I want to acclimate everyone to the IDL process. We're learning lessons along way. One thing we want to emphasize is that going into IDL 4-5 weeks before is when all of the prework is done. Lots of decisions are made. Once get into IDL have to let it run through. Thing that comes out of IDL is not stuck in stone. That's the beginning since this is a process. IDL actually doesn't even get to everything. Some instruments are big and complex and we don't even get to a lot of them. Even for competed AO, some people come through and decide they want trash the whole thing. You can never take what comes out of IDL and say that's what we're going with. We take input and we want to change the process. We had assigned STDT PIs to instruments but I would recommend it shouldn't be just one person. Everyone who wants to contribute to IDL run should become part of IDL run ODLs (optical design labs) that happen several weeks before IDL runs. Suggest people make themselves available. If you can't make it in person you can make it via telecom.

Shawn Domagal-Goldman: You said during IDL run you let it run through. During run itself because we have to get something out of 3 day period so we are going to be more stubborn / resistant to changes.

Julie: But things can change after IDL.

Shawn: Yes. We put our foot down for the week for Matt's sanity.

Aki: I think that more participation in ODL is good. I still think that should be coordinated through instrument leads.

Julie: We want to make sure people have opportunity beforehand to contribute.

Aki: Through instrument PIs.

Marc Postman: For at least two instruments IDL is done. What is process for follow ups?

Matt Bolcar: We're starting to ramp up LUMOS ODLs right now. We can share time and date. Kevin if you can arrange for people to join? Will go up until pre-work meeting. Agreeing with Aki that everything goes through instrument PI.

Marc: Was asking about HDI or coronagraph.

Matt: Good point. I need to work with each PI for instrument on identifying top priority items to be addressed. Have done a little of that on HDI. Need to touch base with Laurent on coronagraph.

Brad: IDL is meant to prove a solution exists. Not necessarily what goes on LUVUOIR.

Dave Redding: What is plan for architecture B? Tech changes between A and B?

Aki: Idea that architecture B is less technologically advanced is not a decision this group has made. Many have intuitively felt that's going to happen but that isn't final.

Dave: One of those decisions that's self-fulfilling. We need to decide now.

Aki: We can't avoid doing that. Only thing decided is size of B is ~9 m. Sometime this fall we will do this for B.

Dave: Want more engagement for architecture B.

Aki: This whole study is really compressed. Two architectures in 3 years not so easy. We can try to start discussing B a little earlier than what I had in the schedule.

Julie: If you have thoughts you don't want to forget for B send to me and Matt and Aki.

Dave: Trades we have been thinking about but haven't put down on paper.

Debra: Jane is online and maybe others so I'd like to have them introduce themselves.

(more introductions)

Debra: Worth taking a minute for everyone to raise concerns or issues even if we can't discuss fully now. Concerns?

Marc: Building upon experience with WFIRST, v important for scientific members of team to work closely with engineering folks and vice versa. Don't have engineering decisions w/ science implications made without that communication. E.g. Dave's comment about architecture B could be ok if science rationale supports.

Lee Feinberg: We have working groups. E.g. ultra stable working group. We have instrument PIs. Seems to me organizational structure is there. Up to people to get involved with groups they want to be involved with.

Aki: One thing we did change is we shifted to biweekly STDT meetings and occasionally those get canceled. Maybe not a great idea. Joint science and tech team is THIS team. Maybe we need to go back to more frequent rate.

Brad: Probably good time to think about ramping up.

Julie: Let me add that I want to emphasize what Lee said. Laurent is PI of coronagraph, Marc PI of HDI, Kevin of LUMOS, etc. Folks who want a say in them instrument design should work through PIs to get all info to GSFC engineering team Much more helpful to have input before hand.

Aki: I think we haven't had enough STDT telecons over last couple months. Study office v busy with IDL runs. I guess we should talk with working group leads and instrument group leads to have more telecons. Last few months since January when IDL runs started, at GSFC we have barely been keeping heads above water. This is all good feedback.

Debra: Other concerns?

Kevin France: At dept colloquiums, people seem to think that there's some LUVOR/HabEx conflict, and that's the first thing people talk about. They don't talk about the science. Communications issue, but this goes all the way from faculty members to visitors. These are people we need on our side.

Brad: We've not reached a stage where we can talk about science program. We have ideas we want to do but we have to quantify this stuff now.

Shawn: Starting in comms working group to come out with products. We need a big push. Think should start at AGU in December, but certainly by Jan AAS.

Brad: Good to have by AGU. Can get feedback and fine tune for AAS.

Shawn: For draft report outline need to think about figures and images.

Aki: We should talk about this tomorrow in communications session. Started working with graphics people at GSFC. Tomorrow during communications session people should discuss key graphics. We need to make a list.

Brad: Anything else? Other concerns? Ok.

Matt Bolcar: LUV0IR Update on Architecture A Design Process

- Discusses top level parameters of the two architectures
- Shows images of notional designs front, back, stowed inside SLS
- Sunshield is not symmetrical because of way doing pointing

Kevin France: When we talked about moving to 3 mirror anistigmat we talked about 4 mirrors?

Matt: There are 4 mirrors.

Kevin: All instruments have pickoff mirrors.

Matt: LUMOS does not. Microshutter array at telescope focal plane. Others have pickoff mirrors.

- FOV 10 arcmin x 8 arcmin
- “field of regard” 2 pi sr, anti-sun

Dave: Small simple obscuration?

Matt: Not for this design. Maybe B will be closer to two mirror RC design.

Marc: To follow up on that, this is an example that one of the killer apps is surveying large number of stars to find large number of plants. If design precludes that from happening...?

Matt: Does not preclude it. Spoken to Laurent and Neil. They prefer unobscured of course but not de facto statement that this precludes high yield studies. APLC designs exist that have similar performances to small unobscured.

Shawn: Also people working on this for vector vortex.

Aki: Central obscuration may be fundamentally bad for vector vortex. Laurent want to confirm APLC can deal with?

Laurent Pueyo: You take a hit but it's not a big step function.

Chris Stark: As far as we know it's a bigger hit to vector vortex.

Lee: Worth explaining why we did size of obscuration we did.

Matt: Large corrected FOV for instruments to participate in. We are already 24 m out from telescope for secondary. That's a very scary distance. Going longer becomes a major engineering challenge.

Dave: Especially when secondary has flexures.

Matt: Being studied.

Julie: Want to remind folks we're coming up with feasibility point designs. We are not advocating either design we generate is design that gets built.

Matt: Also not well optimized designs.

Lee: For reference Webb secondary is 8 m away. Hard to have a clean room big enough. Major challenge for Webb.

- Coatings reasonably good in far UV
 - 65% at 105 nm
 - 91% at 115 nm
 - 85% 115-200 nm
 - 88% 200-850 nm
 - 96% 850 nm – 2.5 μm
- 135 square meters effective collecting area
- 35 nm is diffraction limit

Brad: What does moving segments do to power? (edge sensor data to move mirror sensors)

Matt: Do require power but not major power sink.

Lee: Coolest thing about power aspect is that the heat the edge sensors generates, there are multiplexors are behind mirror where you need heat anyway. Edge sensors substitute for heaters and lower power consumption for heaters significantly.

Lee: You want a linkage system that acts linear. Plan to demonstrate.

Aki: Just to emphasize more strongly, when I first heard you guys were going to make this active mirror, I thought what?? But this is a super awesome idea that might actually make this whole thing feasible. At all times this telescope will be as perfectly shaped as it can be. Not corrected using photons but really fast using edge sensors. Want to emphasize this really really relaxes stability requirements.

Dave: We have edge sensors on ground based telescope. You need to convert to true edge measurement. Issues of linearity, calibration, drift. Having sensitive measurement does not establish will work at 10 picometer level. Let's not be naïve.

Matt: I know needs to be studied.

Dave: Do not cover all of disturbances/drift we will encounter. Do not measure secondary mirror, not measure back end. Need multi tier approach to the problem.

Aki: We are aware. This deals with most rapid disturbances.

Matt: one layer of many tiered cake to solve the problem. Have many systems.

Lee: We are working on control architecture that shows these different loops. I have SPIE paper to put together full picture. We do understand it's an overall architecture. Ultra stable working group started talking about it.

Nick Siegler: How difficult for off axis secondary mirror?

Shawn: For other architectures?

Nick: Would help with starlight suppression?

Matt: We can look into for 9 meter architecture. OST looking at 9 m off axis. Personally if we want to leverage JWST, that deployment scheme for off axis has never done before. Entirely new. This way if on axis we can at least point to JWST.

Marc: Other challenge is HabEx 4 m off axis design can't fit into 5 m fairing. 9 m would not fit.

Julie: Polarization issues.

Shawn: Challenges to off axis separate from controlling primary mirror. Would work for on or off axis design. Moment we got to IDL run where we decided to go with this: because need to heat mirror we had all electronics in place needed to implement scheme. Only reason we wouldn't try is if we decided primary mirror was going to be cold. Not considering cold.

Lee: We are already at 20 m secondary. Imagine 40 m secondary. Big driver is distance to secondary. Also packaging issues.

Matt: Systems level impact.

Dave: I hope issue resolution can be done in quantitative way. I hope trades can be done with integrated modeling tools.

Matt: I support 100% but integrated modeling takes a lot of time.

Dave: Control aspects. Very effective way of coming up with system that can resist disturbances. We have built models.

Matt: slides on HDI

- HDI channels 200nm -1 um (Nyquist sampled at 400 nm), 1 um – 2.5 um (Nyquist sampled at 1.2 um)
- Filter wheels are about 1 m in diameter. Big!
- Channel select mechanism has 6 elements.
- Long exposure instrument: total exposure times of up to 200 hours. Composed of many 200-1000 s exposures each.
- 5 um pixel size. Four 8192x9192 detectors tiled.
- H4RG detector (WFIRST detector)

Kevin France: How is TRL informing decisions about detector tech to use?

Matt: Organic decision made in lab. Went back and forth a couple times on detectors. H4RG TRL 6 if not higher. Want to limit low TRL items. When science dictates that path we go with it though.

- 56 hours for high-precision astrometry calibration data. Need to revisit and see if that's precision required.

Nick Cowan: Calibration needed for every observation?

Marc: Astrometric observations of exoplanets.

Matt: Depends on stability of pixel geometry of detector.

Debra: What causes pixel geometry to drift?

Matt: Thermal stability. Also optical distortion needs to be calibrated. Once calibrate optical distortion and pixel geometry know where everything else.

Lee: If I remember papers on geometry, need stable secondary mirror for long periods of time. Haven't spent a lot of time worrying about that.

Olivier Guyon: Any optic not in pupil plane will create astrometric distortion. We need calibration that goes to picometer level.

Lee: You had idea of spots at primary. Issue of secondary. If we want to do astrometry I think we need to complete the systems story.

Matt: Back when instruments voted on we had astrometry in HDI and radial velocity in ONIRS. We are getting into the details. We may need to make trade on which is most beneficial.

Olivier: For both astrometry and RV we may be in place where it's hard to do on LUVOIR and makes more sense to do in other mission. For astrometry we are not photon noise limited. For RV you could trade this with ground based.

Aki: Anything that can be done on ground or with another facility, we don't want to do on LUVOIR. At moment just trying to find out how hard it would be.

Dave: Especially if done in advance e.g. RV for target selection.

Aki: Advantages not obvious. Maybe Chris can speak to this if time.

Debra: Efficiency of survey with LUVOIR is where you take hit.

Aki: Not as much as you think?

Chris: Knowing when and where to look? If you know what stars Earths are around and can time reasonably well yield will not change much. Efficiency will change.

Aki: Enhancing rather than enabling?

Chris: Unless you consider a starshade then it helps a lot.

Marc: Precision astrometry not just useful for exoplanets. Useful for proper motion of galaxies. Well calibrated focal plane v useful. Not same precision as detecting Earth. Multiple science applications.

Matt: High precision astrometry capability included in IDL study for HDI.

- Block diagram of HDI
- NIR channel has 3 disks. UVIS has 4.

Nick: Can you give intuition for why filter wheels large?

Matt: Lots of filters. Driven by number of filters and diameter of pupil.

- No slides on coronagraph yet since don't have IDL output package yet. Presented on telecon two weeks ago.

Marc: in 1 hour with this telescope you get to 30.5 magnitude 10 sigma.

Aki: I want to clap for Matt. (applause) Engineering team has been fantastic. Matt has worked really hard.

Jason Tumlinson: I want to raise general issue of observing efficiency and overheads with these huge filter wheels. As a general matter, how much and to what extent can you consider time to move these mechanisms that this stage? How long for system to settle down?

Matt: This is a fantastic question. We attach requirements to mechanisms to IDL (temperature, actuations, how much time to make move, etc). Those are inputs we provide to IDL. I try to get idea from them about trade. Minutes vs hours. What is cost. Upfront work of IDL benefits. E.g. coming up with con ops for instrument up front. What is a typical and what is a stressing observation. What will these require? Knowing this helps me figure out requirements for motion.

Aki: In cases where we don't have time to think through before IDL we can revisit.

Matt: IDL not be all end all. In terms of stability question that comes after the fact after we know instrument works. Goes through whole structural model.

Brad: If lots of filters, why not just go down to two filter wheels that counter rotate and damp each other out?

Matt: Can do that. Start with list of filters we need and how big. Can start to allocate them. Need to be smart about how to allocate filters.

Aki: If we did reduce number of filters we reduce number of wheels but don't make smaller. Suffice to say during IDL on both channels was decided to additional wheel to accommodate more solar system filters. We want to have those.

Matt: Big wheels not problem unless don't fit. Problem we ran into on coronagraph.

Marc: 52 slots in UVIS and 30 in NIR. Webb and HST have those kinds of numbers.

Karl Stapelfeldt: Parallel observations with coronagraph? Deep fields?

Matt: That is the goal. Whatever instrument is prime observer they get to dictate what it does. But other instruments can turn on detectors. While observing with coronagraph it controls fine steering mirror.

Karl: Baffling requirements? Stray light?

Matt: That will be done by industry teams.

Karl: Have to wait and see if fits.

Matt: HDI is good. Coronagraph is a work in progress. I think LUMOS won't be a problem.

Shawn: Comment online from Dave Schiminovich: Additional complexity is thinking about fine guidance.

Kevin: For B, going to ask instrument teams to come up with new designs or scale A designs?

Matt: We will start by scaling.

Aki: Up to instrument teams and this group in general about if you want to scale the architecture A instrument or try something different. Assumed coronagraph for B will not be scaled down A.

Matt: ONIRS will be new. LUMOS it's up to you. Coronagraph a different beast.

Lee: We will be in 5 m shroud for B. New cycle will be much more volume oriented.

Aki: With A in SLS we have lots of mass margins. Huge instrument volumes and tons of mass margins. Not case for 5 m.

Matt: We will hurt for mass and volume for B.

Aki: Want to tell how big HDI is?

Matt: It's a little over 1200 kg.

Aki: And we still have mass margin!

Matt: Let's not give the farm away Aki. Still lots of work to be done. Because we have a lot of mass margin we haven't optimized for that.

Marc: Nyquist sampling helps for parallel observations. Don't want to dither telescope. Imager is Nyquist sampled means you don't need to dither.

Lee: Need to dither for cosmic rays? Hot pixels?

Marc: May just live with it for hot pixels. Lots of observations for cosmic rays.

Aki: At some point we should probably have another STDT telecon update on coronagraph. Many black boxes still. Plans for how to deal with.

Matt: Quick status update is the optical design fits into shroud. Biggest issue is mechanisms didn't fit without occulting beam paths. These are filter wheels. Lots of things we will attempt. If that doesn't work need to revisit number of elements in filter wheels. That is on our plate starting this week.

Laurent: About efficiency, when are we going to discuss? Is this when we do MDL when all instruments together?

Matt: MDL is con ops for whole observatory. Rough observing percentages for each instrument. Rough observing campaign. Estimate overheads for instruments. For particular instruments, coronagraph has started coming up with observing plan. I recommend HDI do same.

Aki: Calibration observations too?

Lee: Big deal on Webb is slew time. One reason it takes so much time on Webb is we didn't want to put constraints observationally. We will have good sense of which stars we want to survey. We won't need to do huge slews. Need to do work on figuring out our slews. V difficult to gimble v heavy thing. Never been done. If our slew requirement 10 degrees would greatly help engineering team. Chris can take some of his work and think about efficiency.

Aki: Traveling salesman calculation. Starshade can't do huge slews. We can pick a similar optical path to minimize slew distances.

Karl: 10 degrees not enough for orbit determination. 45?

Matt: 45 reasonable.

Jason: Original program not what will execute. Real program more like HST: all over place all the time. Some exposures 30 s and some 10 hours. Fine to do traveling salesman problem on Chris stars but if other astronomers going to use we can't do that for all.

Rhonda Morgan (ExEP Standards Team): EXOSIMS traveling salesman code already does these problems.

Aki: That could be useful. Thanks.

Debra: Lifetime issues for these instruments?

Matt: No cryogenics. We assume every instrument 5 year lifetime. Telescope we are assuming serviceable and working 25+ years.

Debra: Power source? Solar?

Matt: Assuming solar. Need to figure out how big will be. So far power budget is big but not unreasonable.

Aki: Solar panels can be serviced?

Matt: In principle. Everything on spacecraft side serviceable. On telescope side instrument removal and replacement. Not telescope itself.

Lee: Gimble on Webb. Momentum buildup and then need propellant.

Debra: Thanks Matt for fantastic and informative talk. Coffee break time.

--Coffee Break---

Aki Roberge: Intro to Outlining the Interim Report

- For this F2F goal for primary deliverable for tomorrow is an outline for the interim report. Ideally down to the section level.
- Shows schedule for mission. We need outline done for this month.
- Interim report delivered to HQ in early December. No specific date yet. In November need to “make it pretty.” Will likely take whole month of Nov. October set aside for several reviews (senior advisors, Aerospace Corporation, Goddard Red Team review). Likely will take whole month. Working backward we need to deliver reviewers draft Oct 1 2017. We need STDT review of whole report mid Sept. Finalize complete reviewers draft in month of Sept: make it complete, uniform. Individual writing assignments due Mid Aug. Assess report progress July (joint STDT meeting 5 with HabEx). Writing will take ~2.5 months. So finalizing outline late April.

Karl: Lots of late review times. Nice if we were done if have two whole months for review steps.

Aki: I actually pushed back from what originally had.

Jason: Schedule is edging towards aggressive.

Aki: Not enough time? Too much?

Jason: Marc and I deeply involved in HDST report. As you get further and further towards deadline, number of people you want to have owning the document shrinks. Other thing: need margin built into schedule. Which steps can we allow to slip?

Aki: There is a little margin in here but I won't call it out because then people will target it.

Jason: Every process I've been involved with: reviewers take more time than they say they need. That gives us time to keep working once they have the draft.

Aki: If earlier reviewers done we start working on their feedback/revisions. Month = pace of slowest review.

Julie: I've never met a science team that stops working on product even after given to review team. Review team just reviews what given to them.

Shawn: We are hoping to have some of these reviews done at meetings with reviewers so can collect direct feedback. We need to get a day that works for everybody.

Marc: Assessing whether this is aggressive schedule not depends on what are contents of interim report expected to be.

Aki: Interesting question. We can talk about now. Haven't received guidance yet from HQ about report content, length, etc. Just generic advice to not make it too long. Which I agree with. In absence of guidance we need to move forward by deciding what we want to do. If it makes sense and we like it then we can propose that to HQ as what we want the thing to be.

Marc: A follow up question that ties back to discussion earlier on proof of concept instruments. If for instance a proof of concept instrument doesn't have a certain capability does that mean in science case we are not allowed to talk about that? Is that true or not?

Brad: Need to be specific about which architecture discussing.

Aki: The science of both architectures we can talk about. Need to be careful about matching up specific quantities to specific architecture.

Marc: Imaging not done with 9 m but scalable to 9 m. Not allowed to talk about?

Aki: If can include that in a sensible fashion, should include it.

Shawn: re. IFU discussion, we may want to say if we did have IFU on board in appendix, this is what it would buy us, this is tech required to get science on board. May be a series of deltas not things we need to close on mission to happen but improvements on baseline design.

Aki: Need to emphasize that there's a bit of an a la carte menu. Can imagine swapping instrument suites.

Nick: Re. length. Who is audience?

Julie: Headquarters.

Mario Perez: About guidance, next meeting one of the main topics will be to provide content and schedule for interim report. If you worked on Exo-C and S, you can see difference between those two and what was added in between interim and final. That may provide guidance to this team in absence of anything official yet. About review, HQ group. Since LUVOIR and OST both have senior advisory group, HQ will probably not review science content since already have

good review by those people. Depending on review that you do, both OST and LUVOIR may have different review: focus on implementation.

Aki: As long as we get full value of HQ attention on some area.

Mario: If we called a team to do a review would be v similar to your senior advisory group. Aerospace corporation. Maybe we call different group from Aerospace to do independent review.

Aki: We were promised at some point that two aerospace teams and firewalled ones doing decadal that the two teams would not contradict themselves when time comes. I would ask HQ that these three sub-aerospace sub teams don't come up with wildly inconsistent evaluations from each other.

Mario: Audience bigger than HQ.

Shawn: Question from online from Jane Rigby. Is report public?

Mario: Yes. Everything related to this discussion is public since this is not competition.

Aki: Even more specifically for Exo S and Exo C reports posted online. Audience is everybody: our peers.

Dave: What decadal will look like? Dry run?

Aki: When we write final report it will add more details to our structure for interim. To give place to start from, I jotted down ideas for version 0 outline. For science chapters, I grabbed titles from astro roadmap. Variations to incorporate solar system science. For now I want us to focus on chapters first. In breakouts this afternoon each subgroup to start thinking about sections within relevant chapters.

Illaria Pascucci: Question related to schedule. Time/scheme to have more community input?

Aki: Need to figure out how/when to do in 3.5 month writing block. Good topic for breakouts.

Brad: Can do by soliciting opinions for colleagues at early stage. Report turned in just before major AGU and AAS meeting. At these need to sell the science case to the community and solicit broader input.

Ana Gomez de Castro: European astronomers can be involved?

Aki: As far as science concerned, community is everybody. For hardware things are separate. Whoever wants to provide input, we want them.

Slide for Draft 0:

1. Executive Summary
 - a. Short and inspirational, high level (~3 pages is upper limit, written last)
2. Introduction
 - a. Overview of report in more detail than executive summary but enough detail that a scientist can get solid picture on what whole thing about. State of field in 2030s
3. Are we alone?
 - a. Habitable worlds and biosignatures, ocean worlds of solar system
4. Are we unusual?
 - a. Comparative exo-planetology, solar system workings
5. How did we get here?
 - a. Astrophysics, planet formation, history of solar system
6. How does the universe work?
 - a. Electromagnetic counterparts to gravitational wave sources, haven't developed this science case yet but maybe we should. Or maybe skip this chapter.
7. The LUVOIR telescope
 - a. Architecture A progress
 - b. Architecture B plans
8. The LUVOIR Instruments
 - a. UV-Optical-NIR Coronagraph
 - b. LUVOIR UV multi object spectrograph (LUMOS)
 - c. HDI
 - d. ONIRS
9. POLLUX: European Instrument study of a UV spectropolarimeter.
 - a. Special case; not typical to have European contribution to concept study at early stage. Told by Aerospace that European instrument needs to be separable and independent otherwise Aerospace will attempt to cost it. This chapter is a report within a report.
10. LUVOIR technology development

Debra: Six includes a lot. Origins, future of cosmos.

Aki: We haven't developed physics of cosmos science cases much. Can spend a lot of work developing or a chapter with one big science case. Should talk about it.

Nick: For science case we have to separate POLLUX science?

Aki: Yes, science, tech, design need to all be separated into POLLUX chapter. Otherwise Aerospace will attempt to cost it. This is an artificial situation to satisfy Aerospace. Given POLLUX team their version of a schedule.

Jason: Will that be true of final report? Any POLLUX science needs to be isolated? Hard to draw sharp boundaries. Why are we allowing Aerospace to dictate content and form? HQ has power?

Michael Garcia: Congress has the power.

Jason: Matters to the extent that you artificially allocate science from one instrument to another.

Aki: We are free to disobey what Aerospace recommends. Don't think we should.

Shawn: We can push that science discussion into main part but we'll be charged for it.

Jason: Why can't have science subchapters labeled POLLUX?

Nick: Color coding Pollux?

Aki: I can take that suggestion back to Aerospace. Can POLLUX science be scattered through four chapters if we're super careful about identifying it?

Jason: We don't want to ignore science or shunt to second class status.

Aki: Partly why Aerospace wants to do it this way so they can consider it "not required" science.

Jason: Raises whole host of other issues. Declare anything written in science section to be require science? How will we express some things required and some not?

Aki: Science observations / capabilities need to be represented in those instruments.

Brad: Asking us to write down level 1 requirements?

Julie: Basically baseline science vs non-baseline.

Aki: What we can do: if this is science you want to do, we need \$ tag on all science.

Jason: Evident that they have concepts in their own minds about which things charged and not charged that we don't understand?

Aki: POLLUX a special case. For other instruments we will provide Aerospace with detailed design, MELs, that's what they'll cost. If they look at science case and see we can't do it with instruments costing, that is red flag for them.

Jason: Procedure for iterative discussion as they do their process.

Aki: When time comes for real CATE that is not iterative. We don't get CATE process through STDT. V important to do the group review. I will take POLLUX thing back to them and see what

they say about us being careful about identifying its science in chapters? Jason thinks would flow better if POLLUX science in science chapters and I agree.

Brad: Subsection on POLLUX science?

Aki: If you distribute POLLUX science in pieces throughout each of the 4 science chapters, if you make it one whole section you're back where you started. Then might as well stay in its own chapter.

Julie: Just means we are not going to cost.

Karl: From Exo C experiments, Aerospace didn't pay attention to science discussion sections at all. Just cared about contrast for FOV, contrasts, etc. Don't worry about science case text for Aerospace.

Aki: I imagine those would appear in science chapters.

Karl: Whether those requirements connect to science we describe they won't evaluate.

Julie: We are not evaluating requirements.

Aki: We will use different word.

Karl: Reacting to breakdown of 3 bullet items related to exoplanets and just one to general astrophysics. Unbalanced? Better to breakup general astrophysics more?

Aki: If you want to do that that's fine. Tell me what they are.

Marc: Let working groups consider. I agree with Karl that this looks like HabEx. That's not what LUVOR is. This is a general astrophysics mission.

Aki: These were roadmap chapters and then I made room for solar systems. Turn the astrophysics ones into two compelling questions.

Shawn: Question 4 not really about Earths. About everything else.

Aki: Please make them science questions, not observation types.

Marc: I get idea behind the format.

John O'Meara: I would love to see as a closing section the first 100 days. What are key things we must do with it and close with that. "These are the things we're going to do that will change the world."

- Conclusion: LUVOIR Cycle 1

Aki: Appendices we should have?

Julie: Yes.

Mark: before appendices, we should discuss environment of the field. E.g. 30 m telescopes, etc.

Karl: Join subsection on state of field (HabEx and LUVOIR). I already have to do that for program office. Happy to do exoplanet side of that.

Shawn: We want to make sure cosmic origins colleagues writing with COS part of HabEx team? We don't want a state of field just exoplanets.

Jason: In general given this schedule minimizing coordination is a good idea.

Jane Rigby: We don't need to ask a lot of people? We have TMT, basic set of facilities and problems solved. Aki you mentioned gravitational wave counterpart. Hard to project that.

Aki: From discussion with LISA study scientist, answer is no. Hard to develop multi messenger science case for LUVOIR regime. Our sensitivity so good they haven't modeled EM brightness of gravity wave sources that faint.

Jane: Way to frame: what parameter space has been dealt with? What do we know is unique for us?

Aki: Multi messenger thing needs thought.

Jane: I can help on that.

Aki: Would love it if you take lead on that.

Marc: One possibility is for each science chapters, have box calling out synergy with existing facilities. For exoplanets, put JWST, EMT, TMT. For stellar, different things, etc. Doesn't make sense to lump all into one thing. Fit better into individual chapters with callouts.

Jane: Way to think about: What will solved problems be? At some level we want to say: What are we sure we will have already figured out?

Aki: Karl you are writing up for exoplanets for program office?

Karl: Pretty much. Writing for Exo-S and Exo-C.

Aki: Hoping the section state of field in 2030s. Not separate for exoplanets, COR, solar system.

Marc: Think too long for intro.

Aki: Don't want to repeat ourselves. We have two exoplanet-y chapters and two astrophysics-y chapters. Guess we can put the state of the field in the chapters.

Leonidas Moustakas: Relationship of capabilities to science we do makes sense to call out in appropriate place in report. Marc's suggestion on science resources belongs with relevant science. An appendix that captures overall summary s you don't need to redefine every time.

Karl: Two things: Where field has got to by time LUVOIR launches? While LUVOIR operating what can do we synergistically with existing facilities?

Aki: We need to cover what has been done by 2035, part 2 is what other science will be happening during LUVOIR lifetime? Tell me where these subsections go. Appendix to report? I think if we put most of the material in appendix put a little in introduction?

Karl: Write it and figure out where it goes.

Aki: Karl writing exoplanets one. Volunteer for writing state of astronomy for 2035? Someone in breakout session figure out who is writing for general astrophysics. Solar system too. Think about where you want to put this material.

John: Do you envision for each major question that each will have their own traceability matrix? Or global matrix?

Kevin: Instrument sections?

Aki: I will ask graphics designers if they can come up with something better than a table for traceability matrix.

Questions to ponder slide:

- Make two general astrophysics chapters
- Flow of report?
- Length of report?
- Title of report?

Aki: In report should point out where we can choose differently. Highlight options considered but not chosen.

Matt: Put into instrument chapters? Options for alternative futures.

Brad: Report is one thing but what we need is a science book that has science cases outlined rigorously.

Aki: Sounds like appendix to me.

Brad: Could be appendix or separate document. Need to establish credibility with peers.

Shawn: Need structure we can print different pieces separately. E.g. shorter form for people who don't want to read whole thing. HDST one version.

Aki: In appendices can put details of science performance calculations. In chapters state the result of these calculations.

John: Need some way for all of the simulation tools as they get better defined to be linked to it. Embed tools? Make clear suite of things people can access to see how to make figures.

Aki: We will sprinkle throughout report. Links to tools.

Laurent: Have a python notebook for each figure? Maybe we can start on that now.

Brad: Keep track on which version of simulator used. Free parameters?

Jason: I will say more later but working on way that we can preserve a calculation and recover it later for online tools. We want to recover outputs and inputs. Might imagine link in report takes you to tool with those parameters already set and then you can do departures from that.

Nick: This is what open science is doing. Ray Pierrehumbert book has python code on website for all figures. Modern science.

Aki: Let's be modern. Ok, how long should report be?

Brad: As long as it needs to be...

Aki: Right. We need to get a better sense, but we also want to avoid producing a tome. Finally need a report title that captures whole story. Shawn you had idea?

Shawn: Maybe after lunch I will.

Aki: Need inspiring, cool title.

Shawn: What was John's idea? The story of life? I don't know.

Aki: Any final questions? Let's have lunch.

---LUNCH BREAK----

Brad: Welcome back. We want to have short discussion on outline of interim report. Any additional thoughts? If not we will go into breakout sessions. Cosmic origins, Exoplanets + Solar System, Technology. Different sized rooms for each group. We'll assign by show of hands.

Matt: In tech one, does that include topics of design?

Aki: Yeah.

Brad: takes vote

COS: 12

Planets: 10

Tech: (missed it but it was largest)

Debra: We expect chapter outline for each working group. We reconvene at 3:30.

Exoplanet Breakout Session

Attending: Giada Arney, Nick Cowan, Bekki Dawson, Shawn Domagal-Goldman, Courtney Dressing, Debra Fischer, Olivier Guyon, Mark Marley, Vikki Meadows, Laurent Pueyo, Aki Roberge, Britney Schmidt, Chris Stark, Karl Stapelfeldt

Mark Marley: Alone /Unique categories. Is this the right categorization? Do we like these two chapters?

Debra: What's the purpose of report? Breakdown a structure under these that does these things? Alternative suggestion?

Nick: Instead of "are we unique" what about "how do planets work"?

Bekki Dawson: Illaria who I'd consider closest to my work is in a different group (protoplanetary disks).

Vikki Meadows: I'm fine with this structure. Are we alone / are we weird?

Mark: Do we flip them?

Vikki: No then we bury the lede.

Karl: Alone question has to come to the top.

Nick: Particular question for uniqueness, if you answer that you answer the first question.

Vikki: This is comparative planetology writ large.

Britney Schmidt: And context.

Debra: Alone is biosignatures.

Nick: Are we alone should really just be biosignatures. Everything else you want to do for all planets.

Vikki: but can't interpret without the context of the rest of the planet characteristics.

Nick: Alone part should be subset of uniqueness part.

Life Elsewhere?	Diversity of Systems Are we unusual? Neighborhood
Biosignatures Find HZ planets Ocean worlds	Architecture Comparative atmospheres Surfaces Solar system science

Britney: In science chapters talking about science drivers. In instrument chapters talking about technique.

Nick: You don't know what's what in the field. Planets vs stars.

Courtney Dressing: Unique applies so solar system not Earth.

Karl and Vikki: Please remove unique. Comparative planetology.

Mark: Unique is a tight box.

Aki: But title is "Are we Unusual", not unique.

Courtney: Alone is subset of Unique chapter?

Mark: How about typical?

Britney: Alone is is there life anywhere? Second is how do planets operate?
(Mark renames Alone to Life Elsewhere and Unique to Diversity of Systems)

Aki: Are we unusual is supposed to be about context. If phrasing confusing can be adjusted.

Debra: I did like notion of diversity of systems.

Chris: We keep saying context. We can talk about placing life in the context.

Aki: was thinking about what I mean by these questions. Chapter titles can have a subtitle. E.g. Are We Unusual: What is the Diversity of Planetary Systems?

Nick: We have how the universe works, why not how planets work?

Mark: Structure is what are we looking for?

Version 2:

Life Elsewhere?	Diversity of systems
<p>No characterized Earth twins yet, state of the field, what ELTs doing (M dwarf opportunities); section joint with HabEx → Karl S., Courtney</p> <p>Which worlds are habitable?</p> <ul style="list-style-type: none"> - What does habitable mean? → Ty Robinson / Meadows - Conventional habitability → Robinson/Meadows - Ocean/icy worlds → Britney Schmidt - Alternative habitability → Nick Cowan/Meadows - Search → Stark - Gross atmospheric composition: lambda, R, delta lambda, D → Mark Marley <p>Biomarkers</p> <ul style="list-style-type: none"> - Molecules → Vikki - Detection requirements → Vikki <p>Synergies during the LUVUOIR era (2030s+ capabilities) → Karl, Courtney, Olivier</p>	<p>State of discoveries: RV, few distant atmospheres, hot things, JWST, eclipse and phase maps, WFIRST + ELTs, TESS, CHEOPS, PLATO, solar system (ocean worlds, ice giants, NH to KBO) → Debra, Britney, Jacob Bean, Nick Cowan</p> <p>System architectures: → Bekki Dawson</p> <ul style="list-style-type: none"> - Disks (debris, Kuiper Belts) - Distant planets - Dynamics - Masses - Radii (& albedo) - Rings, moons, solar system → Britney - Multi-star systems <p>Comparative atmospheres:</p> <ul style="list-style-type: none"> - Diversity → Marley - Photochemistry, hazes → Marley, Giada - Clouds → Marley - Evolution, escape → France/Luca - Atmospheric dynamics + solar system → Cowan, Britney <p>Surfaces → Cowan , Britney</p> <ul style="list-style-type: none"> - Hot terrestrials - Others - Solar system <p>Synergies during the LUVUOIR era (2030s+ capabilities) → Karl, Courtney, Olivier</p>

Nick: Sara Seager biosignatures.

Karl: It's just let's make HZ bigger.

Nick: I would put H-rich atmospheres in diversity of systems. If not obvious which planets actually habitable, unless we see exact Earth twin won't be obvious what to look for biosignatures.

Mark: Looking for keys under the lightpost. To start with.

Nick: Want life elsewhere to be first thing they encounter.

Mark: How is LUVOIR unique for ocean worlds?

Aki: Jet monitoring in UV

Britney: And any of the IR stuff as far as we can go is out there.

Aki: Water always better not done from ground.

Britney: All that stuff in habitability question, not separate. Solar system is a case study for some of this stuff for ocean worlds.

Mark: Right don't want it to seem tacked on.

Aki: May swap conventional: earthlike, icy worlds

Olivier: Goal is to map these to measurements we will do?

Aki: I view these as science goals.

Olivier: What is science goal? Ability to identify life

Vikki: What is nature and prevalence of habitable worlds?

Britney: have to storyboard how these all connect to each other.

Courtney: Where are they? We are not going to find Earthlike with TESS.

Vikki: Those are potentially habitable worlds with TESS.

Courtney: UV monitoring in Life section?

Mark: We already have a ton of text on biomarkers.

Vikki: You're welcome. 😊

Aki: We need text on icy moons.

Britney: Pretty easy.

Laurent: Tension between number of things we detect and quality of the detections.

Aki: Chris your argument about 30 Earth candidates to ensure you see habitable conditions given an $\eta_{\text{habitable}}$.

Olivier: Wavelength coverage is elephant in the room.

(discussion about science traceability matrix)

Aki: I want to talk to graphic designer and see if some other way to do show it.

Britney: We've done it with other teams I've been on with science question and checkboxes for instruments. And when you get to instrument section that has specifications. Will help aerospace folks as well.

Laurent: Some sort of matrix so we can bookkeep what everyone is doing. Even if we don't show it in the report.

Debra: Stoplight? Green, yellow, red.

Nick: Glint under habitability?

Vikki: Yes

Mark: Join session with HabEx on what habitable means?

Aki: I thought state of what's been done, what is happening in parallel with LUVOIR

Vikki: JWST and ground based will have M dwarfs.

Aki: Right off bat, point out these things.

Courtney: What about PLATO? (re no Earth twins yet). They could find Earths in HZs around star like sun. We should be careful.

Karl: Who is writing LUVOIR transit case?

Vikki: Jacob Bean is supposed to be doing

Bekki: Is the state of field still own chapter?

Nick: Easier to do with HabEx if own chapter.

Vikki: For Exo-S and Exo-C was subsection of intro.

Aki: Easier to do for those since who science case was exoplanets. Makes more sense to me to put the different state of fields in their proper chapters.

Olivier: There will be overlap in targets for 15 m for these other missions. These will be most interesting ones. Overlap area v interesting.

Vikki: I think we should go after what is unique first. Then complementarity.

Aki: Maybe every chapter should have a last section that is that. Synergies with 2030s.

Vikki: start with state of field and then come full circle with synergies section at end.

Aki: Yeah

Nick: If m dwarf planets have atmospheres, LUVOIR will want to keep beating on them

(discussion about transiting planets, M dwarfs)

Giada Arney: Proxima Cen is potential target for larger architectures if IWA small enough. Nearby, bright.

Karl: For transiting?

Giada: Not transiting. Direct imaging.

Bekki: Where does planet formation go?

Aki: Planet formation should be in where did we come from. Big bang through planet formation. Switch to exoplanets when gas gone. We have to divide it somewhere.

Bekki: We'll have to refer to other chapter.

(discussion of difficulty of getting masses, radii)

Courtney: M dwarfs are hard for RV.

Olivier: If it doesn't transit can't get radius. Not getting 10 um direct imaging because 20 mas apart from star and even with ELT too close to star. 7-10 stars around which you can detect planets. None are M or K type. Basically all solar type stars. Nearby F and A type stars at 10 um.

Karl: Those can't do with LUVOIR because of contrast.

Britney: We should also identify things that are drivers for requirements. Otherwise you have a very long list.

Nick: Most of the drivers on the left (bio stuff)

Vikki: M dwarf planets are very interesting from comparative planetology standpoint.

(more discussion about it being weird to have disks in multiple sections).

Bekki: Hard to put Kuiper Belt in.

Britney: I was thinking about orbit-y things in other sections. And object type stuff here.

Aki: What is orbity?

Nick: Dynamics and formation into other. In this we are studying the planets.

Karl: Architecture related belongs in our side. Chemistry of material in COS side. Structure for us, chemistry for COS.

Courtney: Discussion for full group?

Britney: Hard to organize science.

Aki: Interesting thing about young debris disks is planet formation.

Karl: Mature planets we can get info about studying disk. E.g. mass of planet causing structure on debris disk.

Aki: Not as unique a constraint as I'd like it to be.

Chris: It's degenerate.

Karl: If know where planet is it's not degenerate.

Chris: Mass, migration rate, grain sizes.

Aki: Disk inferred planet masses not nothing but not remotely like RV or astrometry. NASA split is disks are in cosmic origins

Bekki: If everything related to planet formation needs to be in other group. Me and others need to take a lot of these things with us. Pretty different from how we've done this so far.

Britney: Clumping technique and science questions helpful.

Aki: Distinction in my mind between young and old debris disks.

Britney: They're all related. From how to write it...?

Nick: Have to draw line somewhere. Agree with Britney: thematically cleaner line between studying planets vs how planets get there.

Mark: Let's table and discuss in big group.

(discussion of page limit)

Debra: < 100 for interim report?

Aki: Will be tight. I think we can shoot for as much as Exo-S and Exo-C reports were.

Vikki: Shorter shows discipline.

Courtney: We can pick figures wisely.

Aki: Shoot for 100 total?

Karl: Probe studies only 10 STDT members each.

Vikki: So each chapter only 10 pages?

(Missed notes for the end of the discussion)

Cosmic Origins Breakout Session

Notes by Shawn D-G

Top-line structure:

Cosmology, Large Scale Structure + Dark Matter

Galaxies and galaxy evolution

Stars, Stellar Evolution, and the Local Universe

Science themes:

“Understanding all the aspects of atoms in galaxies” as overarching science theme. (I like it.)
“How does structure form?”

Here’s what goes into each template:

Talking about a trade space for 4/6.5/9/15-m apertures – maybe a “checkbox” table of yes/no for different science cases?

Science Traceability Matrix

Callout box (or boxes) for capabilities – like what you can do X hours sort of thing. But science statements not just observation descriptions.

Another callout box (or boxes) for state of the field and how we add to/complement it

State of the science/synopses

Program descriptions – such as to do this right we need to use these instruments in these modes to make these measurements. Get at the idea of combined information from multiple instruments.

Parallel science observation cases? (decided to kick this over to some other section, maybe instruments)

Goal of 6 pages (including figures) for each of three example science cases.

Technology Breakout Session

Leads: Matt Bolcar, David Redding

Post-Breakout Reports

Debra: Reports from breakouts.

Tech Breakout Report

Matt Bolcar

Matt: We went through chapter titles Aki had given us and filled them in.

(Matt gives presentation on technology group)

- Identifying enabling vs enhancing tech

Nick asks question about appendices.

Matt: If we have ITAR section put as appendix removed from public.

Aki: Great! One question I had: work from CAN efforts from industry CAN teams. Where does that come in here?

Matt: Largely included in design reviews. If one of the CAN studies looks at sunshield design, alternatives...merged into it throughout.

Aki: I want the CAN people featured prominently.

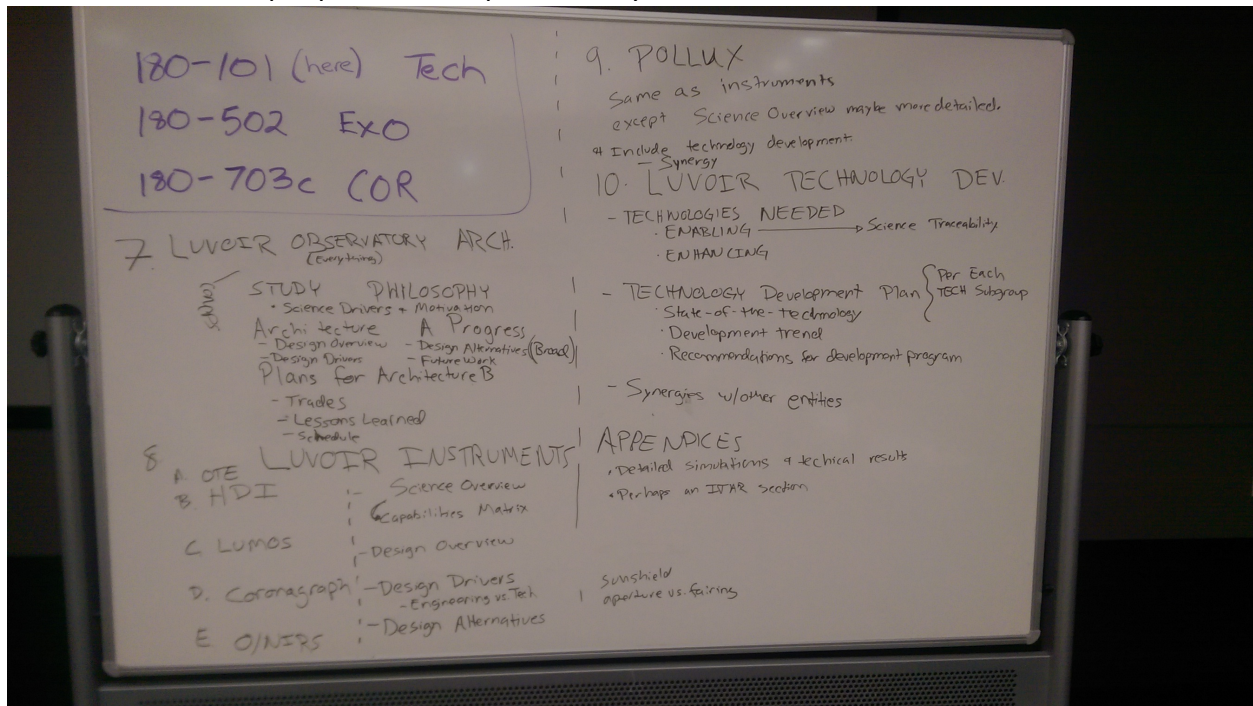


Figure 2: Photo of draft outline for technology chapters.

Julie: They will be authors.

Matt: Tech groups and sub-group chairs

Aki: Worth saying something about CANS?

Shawn: On enabling vs enhancing, one thing in discussion in COR is to come up with checklist on what architectures could and couldn't do.

Matt: One of the key things we talked about is three sections need to be consistent.

Shawn: At some point we should talk about science we get from enhancing tech. Occur in science chapters?

Julie: Be in enhancing tech section. If you try to do a subgroup in science section could start confusing people.

Shawn: That's fine.

Aki: Additional science from enhancing tech brief statements with the enhancing tech.

Matt: I guess so yes.

Matt: We need to figure out how we will capture this at the report level. Big picture level we need to talk about throughout document. On basic level: Here is design and this has to be linked to what science is done.

Julie: Ways to do it. My goal to make it as clear as possible while confusing as few people as possible.

Matt: Worth a little thought as to best way.

Aki: Some of that in design alternatives. Need to discuss logistics of doing this whole thing.

John O Meara: Cosmic origins set up github.

Aki: Virtue of github is version control. Maybe we need tutorial.

Exoplanets Breakout Report

Mark Marley

Mark: Lots of discussion on where to draw line in debris disks?

Aki: Maybe we don't need to figure out right now. Stuff gets written and we can place it later.

Ilaria: (can't hear) Young disks, old disks

Kevin: Feels like debris disks should be with protoplanetary disks.

Karl: Britney and I were discussing a few minutes ago. If talking about a planet clearly on exoplanet side. If talking about planets as a system (forming, migrating, otherwise) better in origins.

Aki: Then that would move debris disks completely into COR.

Britney: I don't think there's right or wrong answer. It's not cosmic origins questions. It's questions about origins. We're stovepiping a little bit. Doesn't look good from top level perspective. We don't have a separate section on solar system objects on purpose. Solar system relates across exoplanets. Fundamental science drivers are the same. Really how structurally it makes the most sense.

Aki: Using that logic, then debris disks moves into origins. Solar system topics about planet formation also in origins.

Karl: Things about planets themselves...

Aki: That stays in exoplanets. Late stage migration in origins.

Chris: Most important studies in solar systems in recent years from debris disks. E.g. Rings, planet 9.

Nick: It's not a demotion. Moving between one awesome title to another awesome title. Moving from diversity of planet systems to how we got here.

Shawn: Can we come back after we talk to solar system people?

COR Breakout Report

John O'Meara

John: We assigned team names based on Star Wars. Either awesome or frightening. Callout boxes in colors e.g. synergies with ground. Uniformity throughout document as visual cue would be a nice thing. Also various science enabled by various architectures. Checkboxes to show what science topics enabled by different architectures.
(shows outline)

discusses callout boxes that are color coded
"Just as important as words are figures."

Package metadata with plots. We suggest other teams do this too. (code, data)

Emphasis that whole report needs to be cohesive.

Aki: I think we should talk about this now.

Debra: Yeah this is the time.

Aki: Obviously aside from the six signature science programs (that COR is doing), vast number of COR science cases that will appear in appendix.

John: Appendix is what I call the LUVOIR science book.

Aki: And that will cover lots more different science applications.

John: Way to most easily flow from compartmentalization of COR to LUVOIR cycle 1 at the end is to have stuff like this on hand.

Aki: If you just made chapters that are laundry lists of all zillions of science cases, they'd all be a short paragraph long.

John: We need to figure out how to turn laundry list of 50 science cases into signature science cases. There is a lot of overlap between them on venn diagram.

Aki: Better than laundry list of things so short they're trivial. Important to capture somewhere full range of COR science cases. I can imagine someone be pissed if their case isn't in there.

Kevin: Brad's monster book of science

Aki: It's an appendix, not a separate book?

Brad: I imagine we put on astro ph.

Aki: If material that supports report needs to be in report.

Brad: ApJ level that justifies numbers in report.

Aki: If it's supplementary detail to justify numbers in the report it needs to be in report.

Brad: Appendix that has several hundred pages?

Shawn: Online supporting material? Other analogy someone had is these might be stapled together white papers for decadal survey.

Brad: No matter what form this takes will be given to decadal.

Aki: Question for decadal study management. Can we put our supplementary material online?

Shawn: Otherwise way too many page or not have enough rigor in the way we do things.

Aki: I wasn't counting appendices against page targets. But I guess if you have 200 page appendices maybe you defeat the purpose.

Nick: Do you guys talk about planet formation? Do you own planet formation?

General agreement COR owns planet formation

Nick: You planet people happy in COR?

Kevin: It doesn't matter. This is the science that bridges exoplanets and COR. This is where they meet.

Nick: Why don't we have separate section on how do planets form? Maybe at same level as Are We Alone? And then Are We Alone? And How Do Planets Form? If it's such a great link, why doesn't it have its own tent?

Kevin: To a degree, will be one of signature science topics in one of the COR chapters. Will be first in order.

John: Yes naturally flows from exoplanet chapter to have it first.

Bekki: My question is what do you do when multiple science questions have the same measurement objective? An example is measuring a planet's orbit. Relevant to formation but also relevant to the individual planet focused questions. Should be mentioned in both places but you don't want to repeat.

Shawn: We need to be careful that exoplanets report is not just coronagraph science case. Need to start with science Qs. If observation pops up more than once I think that's ok.

John: Part of the reason why these boxes pepper throughout about science enabling aspects. You can connect the dots however you wish. As long as it appears in there then people can connect the dots at least mentally.

Aki: To avoid repetition, if measuring orbits discussed in exoplanet chapter but want to use those later, just refer to earlier section about that observation need.

Nick: Science traceability matrix should show these connections.

Aki: Yeah I think we can handle that and avoid repetition with cross-referencing. I guess the way you guys envisioned it is state of science, synergies with what is happening in LUVOIR era. In exoplanets section we had it divided. State of field at top and synergies with LUVOIR era facilities at bottom. Whatever we do for this aspect we need to all do it the same way. How do we want to do it? Together in one box? Split at beginning and end? HabEx and LUVOIR should have same background info.

Nick: Nice to put things in boxes is breaks up linear narrative. I like boxes. But we have the curious case of HabEx and LUVOIR wanting same background information but different missions.

Aki: But HabEx does general astrophysics too.

John: But one box or two?

Karl: I think you need two boxes to do entire treatment of the subject.

Courtney: If box takes up whole page not visually effective.

Aki: How long these bits end up being will dictate what we have to do.

John: We will try to get a fully operational template done up soon to get an idea of what it visually looks like.

Aki: Don't forget you have to coordinate state of field with COR. This is about where state of field will be in 2030s and what other LUVOIR-era facilities can do. Need to be same. For Exo-S and Exo-C reports the same.

Karl: In interim were same but not final.

Aki: They should be the same.

Matt: If we as LUVOIR team settle on callout boxes that will lend itself to a certain format of text that's brief. If HabEx decides no callout boxes will get two sets of text. Fine if have same information.

HabEx team member (not sure who): HabEx general astrophysics is smaller than LUVOIR. We have started having telecons.

John: It will match up, won't be verbatim.

Vikki: They should not contradict each other.

Aki: And they should cover the same key points.

Shawn: Good if OST also agrees on state of field.

Aki: Topic for pause and learn. Highly desirable for HabEx, LUVOIR, OST to all agree on where we will be in 2030. Yes OST comes into this too.

Courtney: Also want people not to be offended if their science case is not considered signature science case. Word cloud so people can find their favorite science words there?

Aki: I think helpful but might not be sufficient. But sounds fun.

Courtney: Should compare word cloud to full document to make sure not missing anything.

Bekki: Another question on planet formation issue. Where do we put observations on physical processes of planet formation; also things you may want to look at for individual system for understanding particular planets?

Illaria: At the moment in cosmic origins.

Bekki: Also at the moment in exoplanets.

Aki: We're not the first group to struggle with this.

John: We have goal of two weeks from today to identify signature science cases

Aki: Do you have ideas for your six signature science cases?

John: Lots of discussion so far.

Aki: Given our short page limits... 30 pages for these three chapters. 30 for exoplanet chapters. 30 for technology. Can you do it?

Matt: I think 30 for each section in tech.

Aki: Well we just went over 120. 40 pages for tech? Introduction and concluding cycle 1...

John: That can be one page. It doesn't have to be more than two pages. Just a happy visionary summary.

Aki: But intro needs to be something like 10 pages. I can live with 120 pages.

Shawn: Mario how does 120 pages sound?

Mario Perez: I think WFIRST scheme was 356 pages of which 200 were in appendix. Main body 150 pages or so.

Marc: Another thing to keep in mind with regard to WFIRST, version published in astro ph is a condensed version for community.

Aki: Hopefully that's our intro chapter.

Mario: Highly recommended you do this.

Aki: When writing intro we should write it intending to be a stand alone document. In ballpark of 120ish sounds ok. Matt 40 is ok?

Matt: We can make it work.

Aki: Oh POLLUX in there too.

Julie: We don't need to do this now.

Marc: TMT science case 200+ pages. They even had a lot of one paragraph short things. Not that we should follow that. I wouldn't over-worry about pages.

Aki: Ok I guess we're ok. I guess I need to tell POLLUX team I gave them a page target that was too long.

Shawn: Do exo folks like structure COR laid out?

Mark: Question is whether we want synergies to be separate box? My take is synergies should be different box.

John: As long as it's a box.

Aki: Ok two boxes. Each chapter has some flexibility to decide where to put it. Wouldn't have to be in same place in every chapter if in box for uniform visual look.

Mark: For Exo C we had professional word document person.

Aki: We'll have that too.

Mark: We should write in word?

Julie: Don't worry yet.

Shawn: Don't worry about formatting; worry about text in whatever form works best for your team. If converting to be done, we will do that.

Mark: I remember at end of exo-C it took a lot of time, this kind of stuff. Mostly on Karl.

Karl: Our documentarian absorbed a lot of different formats.

Britney: Talked about streamline table for some version of science traceability for each section. Format should come top down so each section does that. Great way to minimize number of pages and maximize tech output.

Aki: Yeah.

John: Include in template?

Britney: maybe better to come from project side.

Matt: Standard science traceability matrices unreadable.

Britney: A lot of work in planetary missions to make them more graphic, clearer.

Aki: Do you have examples?

Matt: If anyone knows of good matrices, send it around.

Britney: I will send around.

Aki: If there are other disciplines with better ideas for how to lay this out I want to see them. Can we incorporate this outline for exoplanet chapters?

Mark: We need deadlines.

John: Two weeks from today is finalization of signature science questions. June 15 deadline for first draft of all. Nebulous July. In terms of template decision, we can probably do that quickly.

Aki: That's basically the interim report outline. We need it finalized by end of the month. We should hopefully be pretty close by tomorrow.

Brad: Thank you everyone. Very productive day. Look forward to another half day tomorrow.

Day 2 (Tuesday April 18)

Brad: Welcomes everyone back.

Communications Discussion

Shawn Domagal-Goldman

Shawn

- Shows Joint HabEx-LUVOIR cost slide
- HabEx doing independent costing twice. LUVOIR doing once.

Aki: HQ paying for 1 Aerospace CATE

Shawn: Independent costing happens once or twice but other costings from internal design studies. Multiple ways of getting a cost.

Aki: Out of curiosity, Phil what do you think of slide language?

Phil: I want to remind everyone that single largest cost in mission is science instruments. Number of pixels may be a good estimate of number of cost. I think there are some indications that you can look at number of pixels as cost indicator per instrument. Smaller telescope the smaller proportion it tends to be. If you look at Spitzer, it's 10-15%. If you look at JWST it's closer to 25%.

Julie: 17% for JWST.

Lee: There's subtleties to all this.

Phil: Total mission cost to JWST I am excluding government contribution. No mission prior to JWST had data on what government part of the cost was. JWST total mission cost I would get is phase A-D turns out to be 6.3 billion if you back out phase E which is another billion. Government contribution is probably another billion or so. 20-25% is a different number. It's really really complicated to talk about generalities. I recently did cost estimate for OST and I estimated cost for 9m at 40 K OST telescope would be .6-1.1 billion. In future year dollars 1-2 billion.

Aki: Maybe worth adding a bullet point to that slide to that slide about costing is complicated.

Lee: A lot of the models we've done and cost modeling info for past missions out of all of those only one segmented telescope. Economies of scale can be a benefit.

Phil: I wouldn't hang your hat there.

Lee: We should do a better job of communicating how economies of scale factor in. I can work with Phil offline looking at ground telescopes.

Matt: All of this illustrates costing is really hard.

Phil: My data indicates cost goes with 1.7 the diameter. You're better off building biggest telescope you can afford because if it was strictly as diameter squared then it would be independent of the (unintelligible). More photons per dollar with large aperture telescope than smaller.

Aki: Discounted photons with larger.

Phil: If you look at Chris' models on number of planets. Goes as 1.7 – 1.8 with diameter. Same as cost. Cost per planet is about constant.

Marc: But that's not metric we're using. You need to find the planets.

Aki: Buy these planets get astrophysics for free!

Phil: Segmented telescope being less expensive than monolith idea around for a while. I was looking at data recently and came to realization that segmenting may increase cost. Kind of subtle and not obvious and not even a big effect. Like 5%. We're not ready to publish it yet.

Brad: I have to disagree. We're looking at something bigger than the biggest fairing available.

Phil: If you can't build it with a monolith you're better off. If you can't then you can't.

Shawn: It's complicated. If you ask different people in the room you get different stories. We need to incorporate expertise of Dave and Phil and Lee and Aerospace. Even if not accurate it's precise and a number we can rely on going into decadal.

Dave: Phil I'm wondering about problem with monoliths being large enough to be interesting is that they are way larger than anything built.

Phil: In space, not ground.

Brad: Largest monoliths on ground are 8.4 m.

Dave: But we're not flying those. There are serious challenges in development of space qualifiable mirrors in 4+ m category. Is there history that informs delta in cost with new mirror tech development.

Phil: All my published work is backward looking not forward looking.

Dave: One example is Si carbide Herschel primary. Well below curve for other things. I want to point out there are ways to relax tolerances.

Shawn: I'd like to get back to communications. We have a slide on this to not spend an hour on this at every meeting.

Dave: You have to observe the rituals of our community. (laughter)

Karl: As much as you'd like that chart to be the story everyone buys that won't be the case. At some point our internal cost estimates will leak out there. What do we do then?

Aki: This isn't the slide for all time. This is where we are now. You raise a good point on our internal cost estimate from IDC. It would be good for us to think about what to do with that number.

Shawn: And in context of Architecture A and B being different implementations. B could be significantly less.

Karl: Do we keep cost estimates under wraps? Not obligated to release.

Aki: I think any cost estimate at interim report stage is such a wag. Wildly inaccurate. I'd prefer not to put out these numbers.

Brad: I'm not sure. To first order this is going to cost about the same as JWST. But we don't know that. Could be a factor of 2 or 3.

Lee: I don't know a lot about communications. But I thought better being open. Otherwise open yourselves up to rumors. I think cost we come out with will be LESS than what people think. JWST cost driven by cryo. I don't think people would be upset by what we cost. I don't think it would be one of the huge numbers people have postulated.

Dave: At some point we have to own the cost.

Lee: We need to focus on getting down the cost of the expensive pieces. We need architecture B costs to go down.

Brad: First estimate we get will tell us where to concentrate on where to reduce cost.

Shawn: How about we have a fairly good long discussion on first cost numbers on how to communicate it at that time?

Aki: These are good points.

Shawn: If we did get a Webb cost estimate for 15 m we'd want to scream it from rooftops.

John: Ultimate thing is fourth line (Ultimate responsibility of decadal to just judge science to cost ratio). At end of day decadal decides optimum science-to-cost ratio. Science to dollar ratio is what decadal survey is about.

Britney: When you are coming up with next version of slides, really important thing will be to be very clear on what it includes like margin. Be very upfront on what has been considered is important point. Have to face JWST. We've beat this down with other missions by discussing why costs lower and what cost includes.

Shawn: We will want more than one slide at that point.

Jason: I agree with Britney that there will be a factor of 3 after you quote cost. I guess another important message we have to trot out is that we're not going to come up with a 15-20 billion dollar telescope that will destroy the rest of astronomy by building it. None of that is true. No science piece has cost that much. Whatever we do has to fit into that box somehow. Lessons of JWST can avoid doing this factor of 3 again. We are as a group and a segment of larger community are not advocating to be only mission of this scale ever. This is not a zero sum game. Not advocating no other missions exist by advocating for one expensive mission.

Aki: Those are also good points not captured on slide. Do people want to add points to slide?

Jason: This is good as it is. Stuff we've added to it are talking points.

Aki: Talking points in notes on the slides. John your suggestion, did you want to reprioritize the point?

John: Science per dollar and decadal survey process is the process that evaluates that. What I emphasize.

Aki: Scott Gaudi is showing this slide to HabEx team later this week.

Shawn: Now onto communicating everything else except for cost. Talked to Amber Strong. She told story about when Webb needed science community to rally. Asked community to rally by: if giving colloquium put a bit on LUVVOIR or offer to give brown bag seminar on LUVVOIR. Reach out to different departments. Other thing is if you go to a conference, submit abstract on what LUVVOIR could do for you. Example I have in my head is if it's AbSciCon or Cool Stars, you can say what LUVVOIR can do for astrobiology or observing cool stars. If you give those kinds of talks, I think this issue that Kevin mentioned yesterday about having people not understand our science will naturally get rectified. My experience with Exo-S, I thought it was good when Sara empowered us to speak on Exo-S's behalf. We would like all of you to do these two things and Brad and Debra agree. To help we have tools in communications drive.

- Shows list of conferences schedule

Ana: I am responsible for international working group of (can't understand). Have to report on future of UV astronomy. We are working at 3 levels: different sized missions. One of our key objectives is report on synergies between (can't hear). We can give visibility on these activities here. Will help us a lot of on the working group. (IAU General Assembly meeting). Idea is to use meeting to discuss report.

Shawn: Please add that to it or email us.

Aki: We don't have a spreadsheet category for reports or white papers. Maybe we add this.

Karl: COSPAR meeting taking place in Pasadena in 2018. Supposed to be exoplanet session. July 14-22.

Shawn: Please feel free to add meetings to the conference schedule. Aki will format it nicely.

Aki: Yeah. I think up until now we've used this spreadsheet to record what we've already done. We haven't been listing conferences that we SHOULD be covering.

Karl: We track exoplanet conferences in program office.

Aki: But more for other parts. List for COR?

Marc: Canadian website maintains a list.

Aki: That list is absolutely enormous.

Marc: But that's the nature of general astronomy.

Aki: I guess it's good to identify which are relevant. We can't do all. Have to prioritize and use critical judgement.

Leonidas: Spend quick review once per months on telecons on who is going where.

Shawn: Can also go over what has impending abstract deadline.

Aki: January 2018 AAS will be big splash for all decadal missions. At joint LUVUOIR-HabEx tag ups we need to start talking about coordinating activities. Do joint things at January AAS. No specific plans yet. This is like our debutante ball and needs to be shiny.

Leonidas: Deadline for special sessions coming up in next few weeks. Need to decide soon on special sessions.

- Slide on colloquia and seminars
- Discusses visualizations

- LUVOIR deployment video. After deploys have a shot of it in a lightbox. Imagine an iPhone lit really well. To help show serviceability have instruments slide out. Have “baseball card” statistics pop up next to them.
- Internal resources at GSFC to do exoplanet stuff in particular. STScI COR visualizations.
- Discusses poster idea

Giada: The exoplanet posters are loved by non-exoplanet people and even non-scientists. Can find prints of them on Etsy. Good publicity for us if we make similar.

(discussion about putting slide decks on the Google Drive)

Aki: Marc can you put your slides in PowerPoint format on the Google Drive?

Marc: They're on there in Seminars and Workshops folder.

Aki: Bring that into communications folder.

(discussion of making a tech slide deck)

Aki: We need to make plans for the January AAS. Bit splash for that. We want a splinter meeting like last time. Do we want another tools session? (general agreement)

Shawn: Next version of tools seminar may be the LaTeX templates to make science cases for what LUVOIR can do. Set of science cases for decadal.

John: Optimal version is web form. Want to keep as simple as possible.

Shawn: Like abstract submission?

John: Basically.

Karl: We have opportunity to do something different. We can have special session with breakdowns of 10 minute talks that will individually appear in conference program. We can have 5-10 people that would present in that special session. May have broader impact than splinter session.

Aki: Good idea. We should do both.

Shawn: I'm hearing splinter session that's LUVOIR tools 2.0. And the more urgent need is the special session that is a series of LUVOIR talks.

(May 25 is special session deadline; splinters accepted on rolling basis on fall)

Shawn: John, Jason can you pull together something on splinter session?

John: Splinter and special session?

Shawn: Mario are any HQ wires being tripped here?

Mario: No and all other STDT groups going to do same.

John: Should be one big thing where each STDT delivers summary of interim report at the same time in one session together. If we can have a booth that's basically for the STDTs that would be useful. Have physical copies of interim reports for people to look at – for all STDTs – really important.

Aki: Excellent idea. Just as a matter of practicality, was tiring running back and forth between things at last meeting. Would love to have it in big NASA area to have a big table for decadal studies instead of being distributed around.

Susan Neff: We can ask about this. In my opinion not speaking for HQ that they like to stick with what they've done before. If we start now we have a good chance.

Shawn: We can at least arrange for Exo and COR booths to be together.

Aki: Weirdly laid out.

Susan: You don't want people having to hunt for you in multiple places.

Aki: Let's ask for what we want: one big area for decadal studies.

Susan: You want more than one table.

Aki: A very large table or two. That would be great. We can bring up to decadal studies management team. So: special session with LUVOR science talks, splinter hands on tools session, centralized place in NASA booth for all four studies. I liked STSci touch screen tools. That was cool.

Jason: That one's 84 inches.

Courtney: Can we get "Ask Me About LUVOR" buttons?

Susan: You guys probably want to pay for that out of pocket. Counted as swag.

Brad: If a dollar or two per button we can pay out of pocket.

Shawn: Same folks that do graphics will give first cut at logo.

John: Before closing on AAS question...we mentioned a couple of times coordination with HabEx. I want to understand internally what this means. Rumors fly about LUVOIR and HabEx. What is the message we are trying to send?

Brad: We have to make sure not to give contradictory information. We need consistent messages.

Shawn: I think most people in either study want best thing possible. A big reason to coordinate is to maintain spirit of the pursuit of that end goal in context of that process with a lot of uncertainty. With my scientist hat on LUVOIR is the thing I personally want to have happen. That's what my science bias drives me forward. I'm still on HabEx team because I'm not convinced LUVOIR is something community will receive.

Brad: We've said from beginning that LUVOIR is a supersat compared to HabEx. If LUVOIR is recommended HabEx people should be dancing in the streets. They can do everything they want to and better.

Shawn: Even Scott Gaudi has said this. He just doesn't think it's an option for us. Coordination is to be consistent with each other.

Aki: From my perspective two practical reasons to coordinate and get along is one Brad said about consistency. Also what Shawn brings up. If we start pointing fingers and treating each other as rivals, we both fail.

John: What bothers me, internally to this group we have been somewhat slow at discussing when things happening jointly. Subset of people in the know. Important for us to know what those things are and when happening. As internal communication strategy we can do better.

Aki: It's funny because there are rumors that we're merging teams and other hand there are rumors that we're at each other's throats. Neither is true. Once a month chairs of the teams have one hour telecon tag ups. Idea for coordinating for AAS is kind of new.

John: Would be good to have minutes from those minutes passed on.

Shawn: If you want to have a first order idea in your head of content of those discussions, usually about places we think are sore spots between teams. One reason for cost slide: potential sore spot. Another is agreed tech maturity assessment for four architectures.

Marc: The point is the expertise around this table may have different ideas on what those sore spots are.

Aki: Tell us if you feel there are sore spots between us and other decadal studies. Please. A regular agenda item during STDT telecons should be a summary of joint leadership telecon. Something we should start. We need an agenda for each meeting: IDL run updates, etc.

Lee: One messaging thing we should think a bit about is NASA HQ. A frustration I feel is the way LUVOIR tech is being perceived and graded against other tech. We need a messaging plan of – just as an example – coronagraphy. Great demonstration WFIRST did. Models able to predict small changes pretty well. Impressive demonstration relatable to LUVOIR and builds on long heritage. I get feedback from people who perceive LUVOIR as technologically as risky, etc. I think that's wrong. Telescope tech, segmented mirror tech...I have strong opinion that segmented tech is highly mature. This is all about getting stability and contrast. We need to communicate to science community and NASA HQ.

Aki: There is another joint slide being worked on. Not tech maturity slide but more just distilling technological myths. E.g. you can't do coronagraphy in UV, with segments. I didn't show it here, but then I was looking at it and it isn't super well suited to be a joint slide.

Marc: Joint stuff is good up to a point.

Aki: Maybe I should show it anyway but this particular slide doesn't have to be joint.

Matt: It's not so much HabEx/LUVOIR disagreement. It's an external perception of tech perception not self-consistent or based on stuff LUVOIR actually doing.

Aki: Yes and this is a new development. Exoplanet program office in collaboration with Aerospace took tech gap list from last year and did a TRL assessment on it. Brandon presented it last Thursday. This is a negotiation process. Not done.

Matt: Understood and agreed. Ultimately we agree with bottom line numbers. It's a process. We need to know about it.

Aki: A little out of the blue sky. I think Brendon you were tasked as independent TRL assessment. You interpreted as unable to ask questions on what were doing?

Lee: I actually think Brendon did a great job. I'm targeting perception of NASA HQ that LUVOIR is technologically risky or less mature than other areas. I look at coronagraphy development and years of work on coronagraphy. Two years ago, segmented coronagraph design study through exoplanet office, I had an argument that you couldn't build a segmented coronagraph ever. Couple years later, Neil Zimmerman has APLC design that meets that with obscured aperture. We get 10^{10} contrast. Some people in here may not know this. To me that's huge. We're almost at TRL 6 for segment coronagraphy. I want to go around shouting how positive this news was. Looking at trajectory we're going to get there.

Aki: Can you make a slide you can show that conveys that enthusiasm?

Lee: We talked about mini white paper....

Aki: Slide please!

Shawn: Incorporate into slide deck Matt has to make. We should be a point where the leadership knows about this stuff.

Lee: That's just one example. Others we're working on in stability area.

Aki: We want to have that in hand during pause and learn. There's a target for you.

Karl: First of all ranking of tech inputs from flagship missions was presented at ExoPAG in January. Ranking complete and shown. We haven't left you in the dark.

Shawn: Subset of those tied to LUVOIR.

Karl: Very good if WFIRST encouraged to do testbed test of results. Encourage them to share testbed status. Be cautious that there are good performance predictions of coronagraphs in computer not demonstrated in lab.

Shawn: Point Lee is making is there are multiple approaches to starlight suppression problem we've been pursuing. Want to make sure standards we hold one to are same as standards we hold any to. If ok for starshade to rely on subscale modeling. Coronagraph should also be able to reply on subscale modeling too.

Laurent: First time in 10 years I see models (of something I didn't hear) that predict performance.

Lee: That and they achieved contrast levels they achieved. Two years ago people had arguments about never getting to 10^{10} even in computer. Now we're almost there. Should get press release out and relate to LUVOIR.

Aki: We have people in room involved with it. Can you guys put out a press release about what this group apparently feels is a major milestone?

Laurent: We don't want to claim too much right now. After SR, people will relax.

Aki: There is distinction. This is HCIT result that is still true.

Lee: Who owns results?

Karl: WFIRST owns the results.

Neil Zimmerman: Specific plots I'm thinking of is DMs applied aberrations that matched exactly what model predicted. Very striking to me.

Lee: Neil helpful if you and Laurent can tell story. Message I want to send to anyone building these systems: Models matched so well. Tremendous achievement.

Aki: I realize this is really interesting but we just talked through our coffee break.

Brad: Coffee break now!

---coffee break---

Brad: Discussion about logistics.

Leonidas: Discusses afternoon logistics for tours.

Brad: Now we go into breakout groups and wrap things up. Key science and tech metrics. Same breakout rooms as yesterday. We won't reconvene following this. We will only reconvene for photos and lunch and tours following.

Britney: (discussing Europa traceability graphic) Shawn had idea about using segment as basic shape. Using color throughout document. With Clipper we had three "pillars" that showed up in three colors throughout document. Deciding what exactly those are will help you structurally organize document.

Aki: I suspect what we need to do during next STDT telecon is return to outline and deal with things you've talked about. One thing super quick: do we want to stick with biweekly STDT telecons or increase frequency?

Dave: Have weekly but cancel frequently?

Shawn: Maybe when cancel we try to hit few template points by email. We'll give the once a month HabEx discussions, upcoming meetings.

Aki: Action to develop STDT telecom template. Ok so back to weekly. But not next week. Next one is May 2nd.

Brad: Ok let's go!

Exoplanets Breakout Session

Present: Vikki, Chris, Courtney, Mark, Nick, Britney, Giada, Shawn

Chris: Divide into two alternative futures: one where ground has done a lot of work and know where planets are and other alternative universe where we have no information. Ground based gives minimum mass. Many not terrestrials.

Nick: For terrestrials really matters. For giants not matter as much.

Chris: Many things will not be an Earth mass. Even in scenario with them giving us perfect RV information, it's not perfect.

Nick: Astrometry is great. Talk of SIM-lite type thing that can do Earths under a billion.

Chris: On plans anywhere?

Vikki: Which country?

Nick: US.

Courtney: Peter's was partially funded.

Nick: ExoPAG did white paper.

Healthy Ground/Space	No a priori	Metrics
RV Astrometry -candidates -prioritize	Blind search Multiple revisits, overheads Colors, brightness, orbit tests Grism, low res H2O, CH4 High res characterization CO2, O2	# HZ characterized # planets how well orbits, architecture time family portraits spectra (hierarchy: detected, achieved R=50, high res fiber fed)

Mark: Even for blind we may have some info e.g. Jupiters at 3 AU.

Nick: Solved problem.

Chris: If you see planets go there five more times. Keeps increasing HZ yield.

Vikki: We don't trust colors.

Giada: Colors ok to maybe track separate objects across visits? Although phase color change considerations come into play. Track methane/h₂o band at 1.1um?

Mark: Color didn't even work for brown dwarfs.

Mark: Grism would be valuable.

Chris: Logic tests with two observations. E.g. this planet consistent with this orbit but I'm skeptical of that because semimajor axis is unknown to better than 10-20% unless you have four epochs. These tests rough as color.

Nick: Just need two epochs to separate from background objects. Once moving know they are planets so you keep visiting.

Mark: How long to dig dark hole?

Giada: Low res spectra and pick targets you immediately want to integrate on?

Chris: If have IFS get low res spectra. At some point choice comes if you want to do high res spectra. That's what impacts yield greatly. Coronagraph in general has lower throughput. Something as costly as spectral characterization takes up a huge chunk.

Vikki: Are brown dwarfs always brighter than planets?

Courtney: Brown dwarfs useful too!

Vikki: But there is no IFU on board anymore so that's difficult.

Nick: Aren't we supposed to undo what IDL did?

Mark: WFIRST will have R=50 in optical.

Nick: If digging dark hole is large amount of time you always want spectra.

Chris: Digging dark hole expensive. Changing filter is not as expensive.

Vikki: Isn't this a case for getting crude spectrum.

Mark: Can we put grism in?

(lots of discussion about wanting IFU / grism)

Nick: Sparse field. If you look at NIRISS for JWST, if you look at a crapload of galaxies and smear them out...it's astronomically unlikely.

Chris: Nyquist sampled planets close together. Difficult.

Shawn: If we figure out what R we need, that is useful. We probably want high res spectrum of most planets even if they are not Earths.

Chris: Nice thing about low res IFS with fiber is you have some sort of spectral redundancy. If fiber efficient you can do everything with fiber after you know what looking at.

Nick: Some sort of IFS crucial.

Shawn: If we design IFU as prelim characterization tool to find what we're doing deep dive on. That's different.

Giada: How high res can we get on IFU?

Chris: R=50 reasonable. OWA 30 lambda/D.

Shawn: State of art 64x64 array gives 30 lambda/D arrays.

Mark: So valuable we can live with that hit to OWA

Shawn: Trade of OWA vs IFU.

Nick: I think it's worth it for IFU. Especially in no a priori category. Will help what you're looking at. If you get snapshots of spectra for everything.

Chris: If we go with APLC you have to choose mask with given OWA. That's 10 lambda/D, 20 lambda/D, 30 lambda/D. Already limiting based on coronagraph.

Courtney: Can also go look at stars farther away.

Shawn: Assume for sake of discussion we go with IFU res = 50 and OWA = 30 lambda/D.

Mark: Even if only looks at half the field.

Nick: Still so much better than moving fiber only.

Vikki: Can fiber sample background? Do you have to do sky by chopping off?

Courtney: Useful to have two fibers in case one has malfunction.

Shawn: Only thing we can't do is get two spectra of two specific pixels. You steer light onto fiber.

Vikki: Rotation to help position?

Shawn: Not sure.

Courtney: M dwarfs tend to have 5-6 planets each.

Nick: Most systems likely to have multiples?

Courtney: Yes.

Nick: IFU useful in those cases.

Chris: Planets tend to be in multiplanet systems. Opens up new science if expensive to move fiber around. Low res spectra useful for correlations between types of planets in systems.

Shawn: What if you have IFU in visible?

(now lots of discussion of dichroics and wavelength ranges of channels and desire for vis channel to extend to 1.2 um)

Giada: Lots of value if we're getting just one channel in the IFU if vis channel went from 0.6 to 1.2 um. Visible is basically featureless for many planets.

Vikki: Yes.

Mark: We have to push a lot harder for IFU/grism.

Shawn: There will likely be one on 9 m. Almost certainly IFU.

Mark: What do we want for metrics?

Chris: Different levels of characterization. Detection, different levels of spectra.

Shawn: Infographic of pyramid. Width of triangle in any given layer...

Chris: Want to visualize for different types of planets. Striped pyramid.

Nick: SNR in some delta T.

Vikki: Would be nice to know number of delta T.

Shawn: Natural focus on golden systems. Not use wealth of info on other things.

Courtney: Hierarchy of needs!

Mark: Thanks everyone for this.

Cosmic Origins Breakout Session

Notes missing.

Technology Breakout Session

Notes missing.

GROUP PHOTO AND END OF MEETING