# Request for Information

**Astro2020 Decadal Survey – Early Stage Space Concepts**

**Questionnaire**

**Overview**

Your project is being sent this request for information to help assess its technical readiness and required funding levels for development and implementation. For projects not ready for a start in the next decade, the survey wishes to understand the funding needs for technology maturation, or any technology demonstration activities required to prepare for future implementation.

The National Academies of Sciences, in consultation with the survey committee chairs, have contracted with the Aerospace Corporation to provide an independent Technical, Risk and Cost Evaluation (TRACE). In some cases, the information requested here may be used as input to this evaluation.

Projects being considered by the survey are at different stages of definition, and so we ask that you complete the request for information below to the best of your ability. If you do not have the detail in the format requested, please provide the information you have.

We are not providing strict page allocations for your response -- these should be dictated by project readiness and what you feel you require. We do, however, urge you to be as succinct as possible. We outline the basic structure for the document to guide you in your response. If the requested information exists in publicly available documents you may point to the pages where the information is provided. If you do refer to other documents, please provide copies of them, or links to the location where they can be downloaded.

We also request that you ensure that any written responses or diagrams that you include do not include ITAR/EAR-controlled information, as these responses must be made public if requested.

**Executive Summary**

1. Summarize your science objectives and your technical implementation at a high level. (SH)

Follow report ES + STM; insert technical implementation

Review: ??

1. Summarize the technology maturity of your implementation, listing the demonstrated technologies and the technologies requiring development. (SH)

Follow Report’s technology readiness section

Review: Hannes, Roger

1. Summarize areas where the data to support this RFI are not currently available.

Do we have this? Is this where we discuss foregrounds?

**Science Overview**

Please frame key science questions and how they drive the project implementation. If this information is available through other publicly accessible documents or reports, you may point to the relevant sections, as long as they address the following:

1. Briefly describe the scientific objectives and the most important measurements required to fulfill these objectives. Feel free to refer to science whitepapers or references from the literature. (SH)

Use science section of the report.

Review: Science leads review and insert white paper references

1. Of the objectives, which are the most demanding? Why? (SH)

B-mode measurement; noise level, foregrounds, systematics

1. Present the highest-level technical requirements (e.g. spatial and spectral resolution, sensitivity, timing accuracy) and their relation to the science objectives. (SH or AT?)

From Report’s Requirements Section

1. For each performance requirement, present as quantitatively as possible the sensitivity of your science goals to achieving the requirement. For example, if you fail to meet a key requirement, what would be the impact be on achieving the science objectives?

**Do we need a clarification here? What do we do if we don’t have detailed information**

**Technical Implementation – Instrumentation**

**(SH or AT?)**

Please answer the following, or point to specific pages in existing public documentation where this information may be found:

1. Describe the proposed science instrumentation, and briefly state the rationale for its selection. Discuss the specifics of each instrument (Inst #1, Inst #2 etc) and how the instruments are used together.

2. Indicate the technical maturity level of the major elements and the specific instrument TRL of the proposed instrumentation (for each specific Inst #1, Inst#2 etc), along with the rationale for the assessment (i.e. examples of flight heritage, existence of breadboards, prototypes, mass and power comparisons to existing units, etc). For any instrument rated at a Technology Readiness Level (TRL) of 5 or less, please describe the rationale for the TRL rating, including the description of analysis or hardware development activities to date, and its associated technology maturation plan.

3. In the area of instrumentation, what are the top five technical issues or risks?

4. Fill in entries in the Instrument Table. Provide a separate table for each Instrument (Inst #1, Inst #2 etc). As an example, a telescope could have four instruments that comprise a payload: a telescope assembly, a NIR instrument, a spectrometer and a visible instrument each having their own focal plane arrays. Please identify the basis for the CBE (Current Best Estimate).

5. If you have allocated contingency please describe it, along with the rationale for the number chosen.

6. If known, provide a description of what organization is responsible for each instrument and summarize relevant past experience with similar instruments.

7. For the science instrumentation, describe any concept, feasibility, or definition studies already performed.

8. For instrument operations, provide a functional description of operational modes, and ground and on-orbit calibration schemes. Describe the level of complexity associated with analyzing the data to achieve the scientific objectives of the investigation. Describe the types of data (e.g. bits, images) and provide an estimate of the total data volume returned.

9. Describe the level of complexity of the instrument flight software.

10. Describe any instrumentation or science implementation that requires non-US participation for mission success.

11. Describe the flight heritage of the instruments and their subsystems. Indicate items that are to be developed, as well as any existing hardware or design/flight heritage. Discuss the steps needed for space qualification. Describe any required deployments.

**Instrument Table, Instrument Name**

|  |  |  |
| --- | --- | --- |
| **Item** | **Value** | **Units** |
| Type of Instrument |  |  |
| Number of channels |  |  |
| Size/dimensions (for each instrument) |  | m x m x m |
| Instrument mass **without** contingency (CBE\*) |  | kg |
| Instrument mass contingency |  | % |
| Instrument mass **with** contingency (CBE+reserve) |  | kg |
| Instrument average payload power without contingency |  | W |
| Instrument average payload power contingency |  | % |
| Instrument average payload power with contingency |  | W |
| Instrument average science data rate^ without contingency |  | kbps |
| Instrument average science data^rate contingency |  | % |
| Instrument average science data^ rate with contingency |  | kbps |
| Instrument Fields of View (if appropriate) |  | degrees |
| Pointing requirements (knowledge) |  | degrees |
| Pointing requirements (control) |  | degrees |
| Pointing requirements (stability) |  | deg/sec |

\*CBE = Current Best Estimate.

^Instrument data rate defined as science data rate prior to on-board processing

**Technical Implementation - Mission Design**

Please answer the following, or point to pages in existing public documentation where the information is provided:

1. Provide a brief descriptive overview of the mission design (launch, launch vehicle, orbit, pointing strategy) and how it achieves the science requirements (e.g. if you need to cover the entire sky, how is it achieved?).
2. Describe all mission software development, ground station development and any science development required during Phases B and C/D.
3. Provide entries in the Mission Design Table. For mass and power, provide contingency if it has been allocated. If not, use 30% contingency. To calculate margin, take the difference between the maximum possible value (e.g. launch vehicle capability) and the maximum expected value (CBE plus contingency).
4. Provide any existing block diagrams or drawings showing the observatory (payload and spacecraft) with the instruments and other components labeled and a descriptive caption. Provide a diagram of the observatory in the launch vehicle fairing indicating clearance if you have it.
5. For the mission, what are the three primary risks?
6. Provide an estimate of required propellant, if applicable.

**Mission Design Table**

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Value** | **Units** |
| Orbit Parameters (apogee, perigee, inclination, etc.) |  |  |
| Mission Lifetime |  | mths |
| Maximum Eclipse Period |  | min |
| Launch Site |  |  |
| Spacecraft Dry Bus Mass without contingency |  | kg |
| Spacecraft Dry Bus Mass contingency |  | % |
| Spacecraft Dry Bus Mass with contingency |  | kg |
| Spacecraft Propellant Mass without contingency |  | kg |
| Spacecraft Propellant contingency |  | % |
| Spacecraft Propellant Mass with contingency |  | kg |
| Launch Vehicle |  | Type |
| Launch Vehicle Mass Margin |  | kg |
| Launch Vehicle Mass Margin |  | % |
| Spacecraft Bus Power without contingency |  | W |
| Spacecraft Bus Power contingency |  | % |
| Spacecraft Bus Power with contingency |  | W |

**Technical Implementation - Spacecraft Implementation**

Please answer the following, or point to pages in existing public documentation where the information is provided:

1. Describe the spacecraft characteristics and requirements. Include a preliminary description of the spacecraft design and a summary of the estimated performance of the key spacecraft subsystems. Please fill out the Spacecraft Mass Table and Spacecraft Characteristics Table.
2. Provide a brief description and an overall assessment of the technical maturity of the spacecraft subsystems and critical components. Provide TRL levels of key units, and in particular, identify any required new technologies or developments or open implementation issues.
3. Identify and describe the three lowest TRL units; state the TRL level and explain how and when these units will reach TRL 6. Summarize the TRL of all units less than TRL 4.
4. What are the three greatest risks with the spacecraft?
5. If you have required new spacecraft technologies, developments, or if there are open issues, describe the plans to address them (to answer you may point to technology implementation plan reports or concept study reports, but please enumerate the relevant pages.
6. Describe subsystem characteristics and requirements to the extent possible. Describe in more detail those subsystems that are less mature or have driving requirements for mission success. Such characteristics include: mass, volume, and power; pointing knowledge and accuracy; data rates; and a summary of margins. Comment on how these ass and power numbers relate to existing technology and what light weighting or power reduction is required to achieve your goals.
7. Describe the flight heritage of the spacecraft and its subsystems. Indicate items that are to be developed, as well as any existing hardware or design/flight heritage. Discuss the steps needed for space qualification.
8. Address to the extent possible the accommodation of the science instruments by the spacecraft. In particular, identify any challenging or non-standard requirements (i.e. Jitter/momentum considerations, thermal environment/temperature limits etc.).
9. Provide a schedule for the spacecraft, indicate the organization responsible and describe briefly past experience with similar spacecraft buses.
10. Describe any instrumentation or spacecraft hardware that requires non-US participation for mission success.
11. Provide any special requirements such as contamination control or electro-magnetic controls (EMC).

**Spacecraft Mass Table (kg)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Spacecraft Bus** | **Current Best Estimate (CBE)** | **Percent Mass Contingency** | **CBE Plus Contingency**  |
| Structures & Mechanisms |  |  |  |
| Thermal Control |  |  |  |
| Propulsion (Dry Mass) |  |  |  |
| Attitude Control |  |  |  |
| Command & Data Handling |  |  |  |
| Telecommunications |  |  |  |
| Power |  |  |  |
| Total Spacecraft Dry Bus Mass |  |  |  |

**Spacecraft Characteristics Table**

|  |  |
| --- | --- |
| **Spacecraft bus** | **Value/Summary, Units** |
| **Structure** |  |
| Structures material (aluminum, exotic, composite, etc.) |  |
| Number of articulated structures |  |
| Number of deployed structures |  |
| **Thermal Control** |  |
| Type of thermal control used  |  |
| **Propulsion** |  |
| Estimated delta-V budget, m/s |  |
| Propulsion type(s) and associated propellant(s)/oxidizer(s) |  |
| Number of thrusters and tanks |  |
| Specific impulse of each propulsion mode, seconds |  |
| **Attitude Control** |  |
| Control method (3-axis, spinner, grav-gradient, etc.) |  |
| Control reference (solar, inertial, Earth-nadir, Earth-limb, etc.) |  |
| Attitude control capability, degrees |  |
| Attitude knowledge limit, degrees  |  |
| Agility requirements (maneuvers, scanning, etc.) |  |
| Articulation/#-axes (solar arrays, antennas, gimbals, etc.) |  |
| Sensor and actuator information (precision/errors, torque, momentum storage capabilities, etc.) |  |
| **Command & Data Handling** |  |
| Spacecraft housekeeping date rate, kbps |  |
| Data storage capacity, Mbits |  |
| Maximum storage record rate, kbps |  |
| Maximum storage playback rate, kbps |  |
| **Power** |  |
| Type of array structure (rigid, flexible, body mounted, deployed, articulated) |  |
| **Array size, meters x meters** |  |
| Solar cell type (Si, GaAs, Multi-junction GaAs, concentrators) |  |
| Expected power generation at Beginning of Life (BOL) and End of Life (EOL), watts |  |
| On-orbit average power consumption, watts |  |
| Battery type (NiCd, NiH, Li-ion) |  |
| Battery storage capacity, amp-hours |  |

**Enabling Technology**

Please provide information describing new Enabling Technologies that must be developed for activity success.

1. For any technologies that have not been demonstrated by sub-scale or full-scale models, please provide a description of the technical maturity, including the description of analysis or hardware development activities to date, and the associated technology maturation plan.
2. Describe the aspect of the enabling technology that is critical to the mission’s success, and the sensitivity of mission performance if the technology is not realized or is only partially realized.
3. Provide specific cost and schedule assumptions by year for all developmental activities, and the specific efforts that allow the technology to be ready when required, as well as an outline of readiness tests to confirm technical readiness level.
4. Please indicate any non-US technology that is required for mission success and what back up plans would be required if only US participation occurred.

**Mission Operations Development**

Please answer the following, or point to pages in existing public documentation where the information is provided:

1. Provide a brief description of mission operations, aimed at communicating the overall complexity of the ground operations (frequency of contacts, reorientations, complexity of mission planning, etc.). Analogies with currently operating or recent missions are helpful. If the NASA DSN network will be used, provide time required per week as well as the number of weeks (timeline) required for the mission.
2. Identify any unusual constraints or special communications, tracking, or near real-time ground support requirements.
3. Identify any unusual or especially challenging operational constraints (i.e. viewing or pointing requirements).
4. Describe science and data products in sufficient detail that Phase E costs can be understood compared to the level of effort described in this section.
5. Describe the science and operations center for the activity. Will an existing center be expected to operate this activity? How many distinct investigations will use the facility? Will there be a guest observer program? Will investigators be funded directly by the activity?
6. Will the activity need and support a data archive?

**Mission Operations and Ground Data Systems Table**

|  |  |
| --- | --- |
| **Down link Information** | **Value, units** |
| Number of contacts per day |  |
| Downlink Frequency Band | GHz |
| Telemetry Data Rate(s) | bps |
| S/C Transmitting Antenna Type(s) and Gain(s) | DBi |
| Spacecraft Transmitter peak power | W |
| Downlink Receiving Antenna gain | DBi |
| Transmitting Power Amplifier Output | W |
| **Uplink Information** | **Value, units** |
| Number of Uplinks per day |  |
| Uplink Frequency | GHz |
| Telecommand Data Rate | bps |
| S/C receiving antenna type(s) and gain(s) | DBi |

**Programmatics and Schedule**

Please answer the following, or point to pages in existing public documentation where the information is provided:

1. Provide an organizational chart showing how key members and organizations will work together to implement the program.
2. Provide a table and a 5x5 risk chart of the top 3 risks to the program. Briefly describe how each of these risks will be mitigated and the impact if they are not. (Mass, power, schedule, cost, science, etc.).
3. Provide an overall (Phase A through Phase F) schedule highlighting key design reviews, the critical path and the development time for delivery required for each instrument, the spacecraft, development of ground and mission/science operations etc. Include critical on-orbit events such as maneuvers, instrument deployments, etc.
4. Provide a description of any foreign contributions and their extent.

**Cost**

Please answer the following, or point to pages in existing public documentation where the information is provided:

1. Provide FTE estimates and cost by year/Phase for all expected science personnel.
2. If a foreign agency is assumed to be a partner or a major contributor, provide an estimate by year and Phase for the cost breakdown between NASA and any foreign contributions. This should be separate, but consistent with Total Mission Cost Funding Table.
3. Provide a description and cost of what will be performed during Phase A by year. Also include total length of Phase A in months and total Phase A estimated costs.
4. Please fill out the Mission Cost Funding Profile table assuming that the mission is totally funded by NASA and all significant work is performed in the US.
5. For those partnering with foreign or other organizations, provide a second Mission Cost Funding Profile table, Table 5, and indicate the total mission costs clearly indicating the assumed NASA and contributed costs.

**TOTAL MISSION COST FUNDING PROFILE TEMPLATE – US Only**

 (FY costs1 in Real Year Dollars, Totals in Real Year and FY2020 Dollars)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Item | Prior | FY2020 | FY2021 | ... | FY2033 | Total(Real Yr.) | Total(FY20$) |
| Cost |  |  |  |  |  |  |  |
| Phase A Concept Study  |  |  |  |  |  |  |  |
| Phase A Tech. Dev. |  |  |  |  |  |  |  |
| Phase B-D Development |  |  |  |  |  |  |  |
| Launch Services |  |  |  |  |  |  |  |
| Phase E |  |  |  |  |  |  |  |
| Science |  |  |  |  |  |  |  |
| Other Phase E Cost |  |  |  |  |  |  |  |
| Phase E Reserves  |  |  |  |  |  |  |  |
| Total Phase E |  |  |  |  |  |  |  |
| Education/Outreach |  |  |  |  |  |  |  |
| Other (specify) |  |  |  |  |  |  |  |
| Total Cost | $ | $ | $ | $ | $ | $ | $ |
|  |  |  |  | Total Mission Cost | $ | $ |

1. Costs should include all costs including any fee

 **TOTAL MISSION COST FUNDING PROFILE – With Partner Contributions**

 (FY costs1 in Real Year Dollars, Totals in Real Year and FY2020 Dollars)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Item | Prior | FY2020 | FY2021 | ... | FY2033 | Total(Real Yr.) | Total(FY20$) |
| Cost |  |  |  |  |  |  |  |
| Phase A Concept Study  |  |  |  |  |  |  |  |
| Phase A Tech Dev |  |  |  |  |  |  |  |
| Phase B-D Development |  |  |  |  |  |  |  |
| Launch Services |  |  |  |  |  |  |  |
| Phase E |  |  |  |  |  |  |  |
| Science |  |  |  |  |  |  |  |
| Other Phase E Cost |  |  |  |  |  |  |  |
| Phase E Reserves  |  |  |  |  |  |  |  |
| Total Phase E |  |  |  |  |  |  |  |
| Education/Outreach |  |  |  |  |  |  |  |
| Other (specify) |  |  |  |  |  |  |  |
| Total NASA Cost | $ | $ | $ | $ | $ | $ | $ |

1. Costs should include all costs including any fee