General Examinations - Primary Area - Day 2

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1 Glossary

Please review the Glossary you started on Day 1. Consider what new terms need to be added. Also, for cases in which you selected a definition from another author, consider whether you fully agree with that author's definition or whether you want to edit any definitions from literature. Share why you want to revise the definitions.

Note: Green indicates that text came from Day 1. Black text is new to Day 2.

Language in general and technical jargon (of which this glossary qualifies) in particular is intended to communicate. This requires that both the speaker and the listener have some common understanding of the terms used. For this reason, I rarely find it helpful to generate new definitions for commonly used words, except to clarify when there is some significant discrepancies in how the term is commonly used. It is generally preferable to coin a new term if a new meaning is required (see, for instance Myoa Bailey's coining of the term *misogynoir* [1] or the significantly less elegant socio-environmental-technical system in this document).

Collaborative Systems: A system that is not under central control, either in its conception, development, or operation. They tend to be assembled and operated through the voluntary choices of the participants, not through the dictates of an individual client [2].

Decision Support System (DSS): A technical system aimed at facilitating and improving decision-making. Functions can include visualization of data, analysis of past data, simulations of future outcomes, and comparisons of options.

geographic information system (GIS): Any digital system for storing, visualizing, and analyzing geospatial data, that is data that has some geographic component. The term can also be used to discuss specific systems, a method that uses such systems, a field of studying focusing on or involving such systems, or even the set of insitutions and social practices that make use of such a system [3].

Multidisciplinary Optimization: A methodology for the design of systems in which strong interaction between disciplines motivates designers to simultaneously manipulate variables in several disciplines [4].

Multi-Stakeholder Decision-Making: Any decision-making process in which more than one stakeholder must collaborate to reach a decision [5]. This can take a variety of forms, including cooperation, negotiation, voting, or consultation [6].

Observing System Simulation Experiment (OSSE): A method of investigating the potential impacts of prospective observing systems through the generation of simulated observations that are then ingested into a data assimilation system and compared to other real-world data or other simulated data. Most commonly used for remote observation satellite design for purposes of meterology [7] .

Organizational Policy: Policy, decision-making, and politics within an organizational stakeholder. This includes decision-making policies, mechanisms of institutional learning and memory, capability development, etc. See the Day 1 Response for further discussion.

participatory geographic information system (PGIS): A subset of GIS that seeks to directly involve the public and other stakeholders, including government officials, non-governmental organizations (NGOs), private corporations, etc [8]. It should be noted that these means involvement in both the production of data and in its application, not merely one or the other [9, 10]. This is to be contrasted with the older term, public participation geographic information system (PPGIS), which focuses specifically on the involvement of the public and not that of government agencies or other organizations [8].

Planning: "the premeditation of action, in contrast to management [which is] the direct control of action" [11]. In general, planning tends to concern itself with more long-term affairs that management does, during which it strives for the "avoidance of unintended consequences while pursuing intended goals." Models, and their specific implementations as decision/planning support tools, are one means of achieving this. The term is often prefaced with 'urban' or 'regional' to indicate the specific spatial scale under consideration.

Planning Support System (PSS): A type of DSS specifically designed to support urban or regional planning efforts. These often involve longer time scales and more general/strategic decisions than most DSSs.

Remote Observation: Any form of data collection that takes place at some remote distance from the subject matter [12]. While there is no specific distance determining whether a collector is 'remote,' in practice this tends to mean some distance of more than a quater of a kilometer. Handheld infrared measurement devices are thus usually excluded (and thereby classified as *in-situ* observatoins. Aerial and satellite imagery are definitively in the remote observation category. Low altitude drone imagery, particularly when the operator is standing in the field of view, is a gray area that is not well categorized at this time.

Scenario Planning: A particular form of planning that focuses on long-term strategic decisions through the represenation of multiple, plausible futures of a system of interest [13]. These futures are often generated by models such as Environment, Vulerability, Decision-Making, Technology (EVDT).

Sustainable Development: The integration of three separate, previously separate fields: economic development, social development and environmental protection [14]. These fields are alternately described as "as interdependent and mutually reinforcing pillars" [14, 15], and as 'conflicting' [16]. Earlier definitions tended to focus on economic viability of future generations [17], but this meaning is largely considered obsolete.

Socio-environmental System: The complex phenomena that occurs due to the interactions of human and natural systems [18]. See the Day 1 Response for further discussion.

Sociotechnical System: Technical works involving significant social participation, interests, and concerns [2]. See the Day 1 Response for further discussion.

Socio-environmental-technical System: A system in which social, environmental, and technical subsystems are linked together in such a way that none can be neglected without compromising the modeling, planning, or forecasting objectives at hand. This can be seen as the combination of the terms sociotechnical system and socio-environmental system. Note the particular emphasis on the needs of the observor, not the inherent system itself, as virtually all systems on Earth can be viewed as Socio-environmental-technical Systems. See the Day 1 Response for further discussion.

Stakeholder Analysis: Identifying, mapping, and analyzing the stakeholders in a system and their connections to one another in order to inform the design of the system. This involves both qualitative and quantitative tools, such as the Stakeholder Requirements Definition Process [19] and Stakeholder Value Network Analysis [20]. It should be noted that this term is commonly used by systems engineers but is not clearly defined as some specific list of methods. In a Space Enabled context, it commonly refers to the coding of qualitative interviews with stakeholders to elicit such items as needs, desired outcomes, and objectives. These are then often analyzed in some other method, such as Stakeholder Value Network Analysis.

Systems Architecture/Architeting: As defined by Maier, the art and science of creating and building complex systems. That part of systems development most conerned with scoping, structuring, and certification [2]. This tends to refer to the high level form and function of a system, rather than detailed design. Other's, such as Crawley prefer to characterize it as the mapping of function to form such that the essential features of the system are represented. The intent of architecture is to reduce ambiguity, employ creativity, and manage complexity [21]. Arguably this is a more specific formulation of Maier's definition. In general, Space Enabled and I tend to use Crawley's definition, both due to its clarity, and for the various qualitative and quantitative methods that have been developed to work well with this formulation.

Systems Engineering: An interdisciplinary approach and means to enable the realization of successful systems. It focuses on holistically and concurrently understanding stakeholder needs; exploring opportunities; documenting requirements; and synthesizing, verifying, validating, and evolving solutions while considering the complete problem, from system concept exploration through system disposal [22]. Something missing from this definition is that systems engineering refers to a specific intellectual tradition that arose out of mechanical, civil, electrical, and aerospace engineering fields in the early-to-mid 20th century. It thus tends to draw from an engineering mindset and relies upon engineering techniques, rather than those of urban planning, architecture, or program management, all of which also could be considered to fall into the above definition. See the Day 1 Response for further discussion.

Tradespace: The space spanned by the completely enumerated design variables, i.e. the set of possible design options [23].

Tradespace Exploration: A process by which various options with a tradespace may be examined and compared in the absence of a single utility function, such as when multiple stakeholders are involved or multiple contexts with no clear priority exist [23].

2 Expanding EVDT

"Please review your response to item # 7 from Day 1 and write an updated response with any additional or expanded ideas. Further highlight the vision for the future use of EVDT and "what you expect to be the challenges of expanding EVDT in future work by a wider community.'"

Note: Green indicates that text came from Day 1. Black text is new to Day 2.

Prior to discussing challenges, it might be worthwhile to briefly discuss the envisioned trajectory of EVDT. To that end, here are some general goals of this research endeavour:

1. Facilitate sustainable development. This is primarily accomplished by linking together different domains as discussed earlier.
2. Lowering the barriers to access relevant datasets and analysis methods in general, and remote observation data in particular. This means not just getting it in the hands of more researchers, but getting it in the hands of more laypeople as well.
3. Building a community of practice around Socio-environmental-technical System (SETS) applications.

At the moment, EVDT is still in its initial stages. While we have international partnerships involving several different projects at the moment, it is still fundamentally a Space Enabled endeavour. Furthermore, while prototypes have been made, in none of the ongoing projects has it reached an operational stage that has been actively used by collaborators or commuity members (though we are getting closer to this). One or more operational applications are necessary to demonstrate viability to the relevant audiences. Once this is accomplished, the next step should be to consolidate and standardize the underlying code, so as to facilitate furture improvements, as well as the reuse of materials for future contexts. Certain key functions that are currently missing in the EVDT prototypes will need to be added, including the easy importing of new datasets and the easy exporting of analysis results and visualizations. Additionally, the individual models and functions should be easily separable and able to be recombined.

Once the initial round of consolidation and standardization is complete, both the EVDT code and the application itself will need to be made available online, ideally through a browser interface. The former, which is already accomplished for the current prototypes, is necessary to enable collaboration between various developers. Strong online norms and collaboration tools already exist for open source projects. As is currently the case, the initial code moderators will be Space Enabled affiliated, with contributions welcomed from anyone and anywhere. As individuals become well-known and respected contributors, they will be invited to become moderators. Furthermore, by making the code available on an MIT license, we are enabling forking and the development of more closed-off variants, which may be necessary for some treatments of sensitive data.

The latter (making the application available online), which is only partially accomplished at the moment, is necessary to expand the userbase. While the internet is not universally available (and disparities of access should certainly be kept in mind moving forward), having an in-browser accessible version dramatically lowers the barrier-of-entry for EVDT.

As the number of applications increase and the code is refined, the various models used in the applications may themselves be the first members of an openly accessible library of models. Potential user groups could adapt and reuse EVDT components in other applications, without having to start from scratch. Initially this would likely still require significant code expertise, but it is entirely possible for functionality to be created to allow for 'plug-and-play.' A user may be able to, in browser or on desktop, select a geographic area of interest (e.g. the Sóc Trăng Province of Vietnam), select an environmental model (e.g. coastal forest health), a societal impact model (e.g. cyclone vulnerability), a decision-making model (land use conversion and conservation policy), and a technology model (satellite versus in-situ monitoring), all without writing a line of code (though perhaps being required to import new datasets themselves). All of this would require that a sufficiently large library of models be built up.

In addition to model interoperability standardization, the code moderators will need to specify accessibility norms as well, so as to ensure usability by individuals with a wide range of backgrounds. Existing prototypes have made some steps in this direction, by having multiple language options available. Thus far, this has been accomplished by existing language knowledge of code moderators as well as the occasional volunteer translator, but some more targeted efforts may be required in the future to specifically recruit translators for targeted languages.

Language is not the only accessibility barrier, however. Terminology, presentation, and interactiveness can also be differentiately accessible to different individuals, depending factors such as educational or cultural background. That said, these difficulties can be addressed via some of the same methods that are already core to the EVDT methodology: namely partnerships with local collaborators; stakeholder analysis; and iterative, participative design.

Recruitment should not prove to be overly difficult. MIT in general and Space Enabled in particular enjoy a high profile globally. Our research group already has numerous national and international connections with government officials, academic researchers, and local community leaders. Even without a complete and compelling example, there has been significant interest in EVDT and its variants. Once a set of initial examples have been finished and publicized, it should be fairly straightforward to expand invitations and recruit contributors (some of the different forms of potential contributions are discussed further in Section 4.

Another consideration in the future of EVDT are the types of applications that it will be used for. Some potential applications include:

1. To inform sustainable development policies.
2. To educate on the connections between the different EVDT domains.
3. To facilitate the exploration and evaluation of sensing technology architectures for particular applications.
4. To facilitate scientific research on ecosystem services and/or the impacts of human behavior on the environment.
5. To provide a basis for studies of the effectiveness of different DSS attributes (visualization techniques, workshop formats, etc.).

A subset of these potential applications are visualized in Section 4.

These applications are varying levels of interest and importance to different stakeholders, and some could potentially be viewed as competing for development resources and focus. For instance Item 3 requires a functional model of the relationships between different remote observation design parameters and performance parameters, along with a means of visualizing and exploring the tradespace. A user who is predominantly interested in Item 1 may find this functionality irrelevant or outright distracting.

On the other hand, some applications are more complementary. While the Item 1 is likely to be a government official or community member while the Item 5 user is likely to be an academic researcher, the findings from an 5 would result in the design of EVDT being improved, so as better serve the needs of the Item 1 user.

Ideally, EVDT would be open to all these applications and more. In practice, care must be taken so that interests of one user group do not unintentionally dominate those of others or, worse, that the interests of the developers do not send them on a path counter to the interests of the users. As EVDT team completes our first round of case studies, it would thus be worthwhile discussing and clarifying who the primary intended users EVDT are and how the interests of these different groups should be prioritized.

3 EVDT

Please review your response from Day 1 to Item # 4. Revise the response as needed to further explore "whether EVD&T (Environment, Human Vulnerability or Benefits, Decision Making and Technology Design) are appropriate concepts to select as the core of a customizable modeling framework." Would it make sense to include other concepts as the core of the EVDT model?

Note: Green indicates that text came from Day 1. Black text is new to Day 2.

While the specific EVDT framework is new, the previous sections have made it clear that integrated, multidisciplinary modeling involving the relevant fields has a long tradition. EVDT is a framework for considering and modeling SETSs, which themselves are the combination of Sociotechnical systems (STSs) and Socio-environmental systems (SESs), as seen in Figure 1. It is natural that just as we would want to expand our consideration of technical systems to sociotechnical systems and of social systems to socio-environmental systems, so too would we want to consider all three components together.

This however only explains the desire of an EVDT-like framework, not EVDT in particular, why does EVDT have four components when I have only enumrated three thus far?

It is necessary to address the latter question first. The answer is that most treatments of STSs and SESs mask two different types of "social" components to the systems in question. For example, Tripod is a "smartphone-based system to influence individual real-time travel decisions by offering information and incentives to optimize system-wide energy performance" [24]. Tripod is built on the TripEnergy model, which in turn combines an environmental submodel (vehicle emissions), a societal impact submodel (energy consumption and trip lengths), and a human decision-making model (driver behavior) [25]. Tripod adds further detail to the human decision-making model, by having a built in estimation of impact of different incentives to influence driver behavior. Finally, Tripod itself is a technological system impacting the other domains. Thus

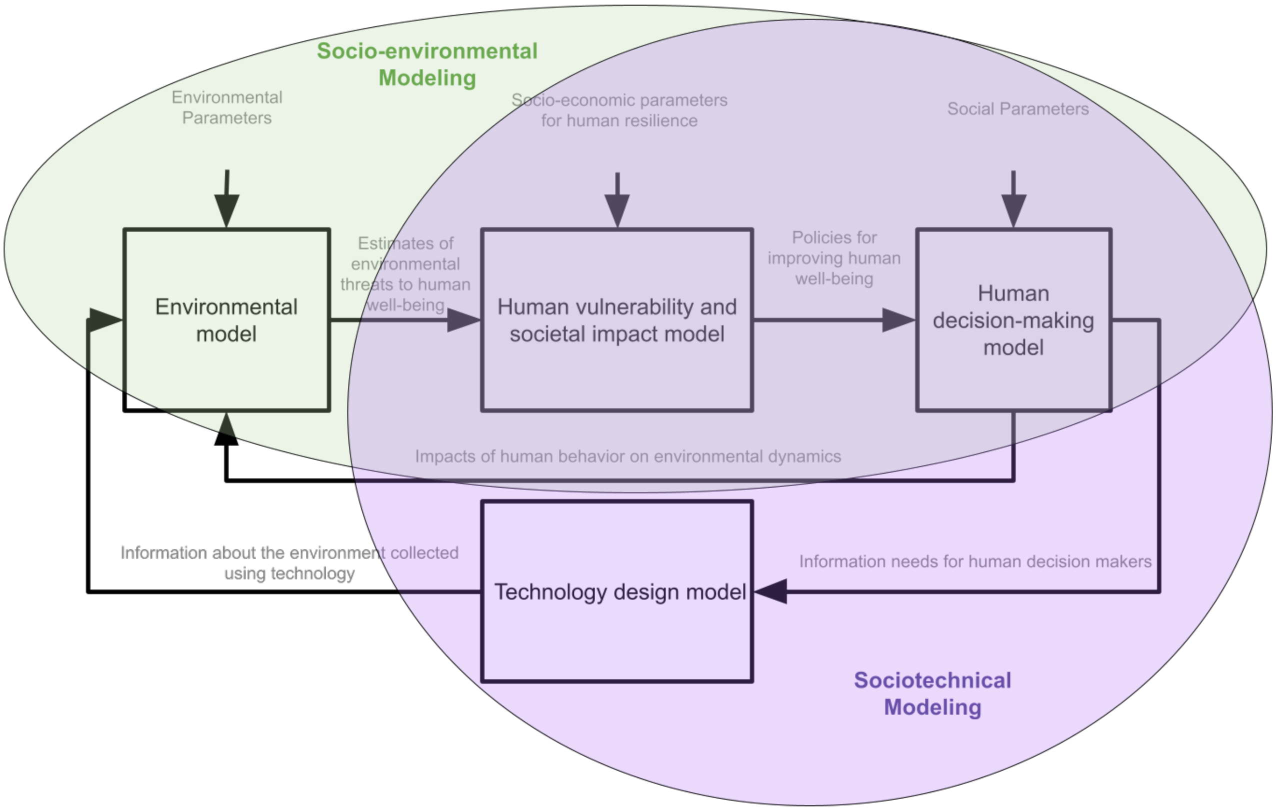

Figure 1: EVDT Diagram with overlaps domains of socio-environmental systems and sociotechnical systems

Tripod is an instance of a SETS, though its creators do not refer to it as such. We can see here that 'socio' can refer to the impact on humans (economic, health, educational, etc.), the behaviors of humans, or both (as in Tripod). EVDT must therefore make such a distinction, spliting 'socio' into the vulnerability / societal impact and human decision-making.

This set of four models with the particular linkages shown in Figure 1 are not the only form that EVDT can take, merely the most general arrangement. Some applications may involve replacing a model with a human-in-the-loop (e.g. having the user themself substitute for the decision-making model) or omitting a model altogether. For other applications, it may make sense to conceptually break a model into two or more components. In the Vida project, which is the multi-context COVID-19 application of EVDT, it was considered worthwhile to seprate the social impact model into two components, one focusing on public health (the obvious priority when dealing with COVID-19) and one focusing on non-health metrics (such as income, employment, etc.). Such a separation can be useful if either significantly different modeling methodologies are going to be used or if the linkages with the other EVDT components are different from one another. Further discussion of some other possible arrangements of the EVDT components can be seen in Section 4.

One way to determine the optimal arrangment of EVDT components is to consider what questions the user or researcher is seeking to answer with this application of EVDT. For instance, the default EVDT arrangement shown in Figure 1 was motivated primarily by the following four questions:

1. What is happening in the natural environment?
2. How will humans be impacted by what is happening in the natural environment?
3. What decisions are humans making in response to environmental factors and why?
4. What technology system can be designed to provide high quality information that supports human decision making?

Alternate questions may result in a different configuration or set of components. The point of EVDT is not to insist upon a particular set of linkages and feedbacks, but rather to encourage a consideration of such linkages between domains in general, and to consider them through a systems engineering perspective.

4 Graphics

Start the process of creating a graphic and accompanying text to communicate the motivation and scope for EVDT and outlines a research agenda that other scholars can join in the future as the EVDT community expands. Build from your responses to the prompts above. Who is the audience for this graphic and text?

This prompt brought to mind three different sets of purpose and audience. These are as follows:

- Figure 2: A simple, highly stylized graphic for communicating the concept of EVDT with the general public.
- Figure 3: A flowchart depicting how EVDT will develop over time and the roles of the different communities involved in that process.
- Figure 4: A set of flowcharts depicting different configurations of EVDT for accomplishing different research objectives.

Below, I go into more detail about the design and intentions behind each of the graphics.

Figure 2 is intended to be readily understandable by an audience with a wide variety of educational, cultural, and linguistic backgrounds. For this reason, the default version, shown on the left, uses no words, only iconography. The version on the right seeks to situate the viewer and thereby invite their participation. This version requires the use of text (at least I haven't though of an alternative), but fortunately it is text that should be easily translated into most other languages. In many ways, Figure 2 is seeking to play a similar role to the standard Sustainable Development Goal (SDG) poster or to the Space Enabled "six space technologies" and "six research methods." In fact, several of the icons are adapted from these sources, while others were made to match the same style. These icons seek to be as close to universally intelligable as possible, rather than relying on particular cultural symbols (e.g. a dollar sign to represent money).

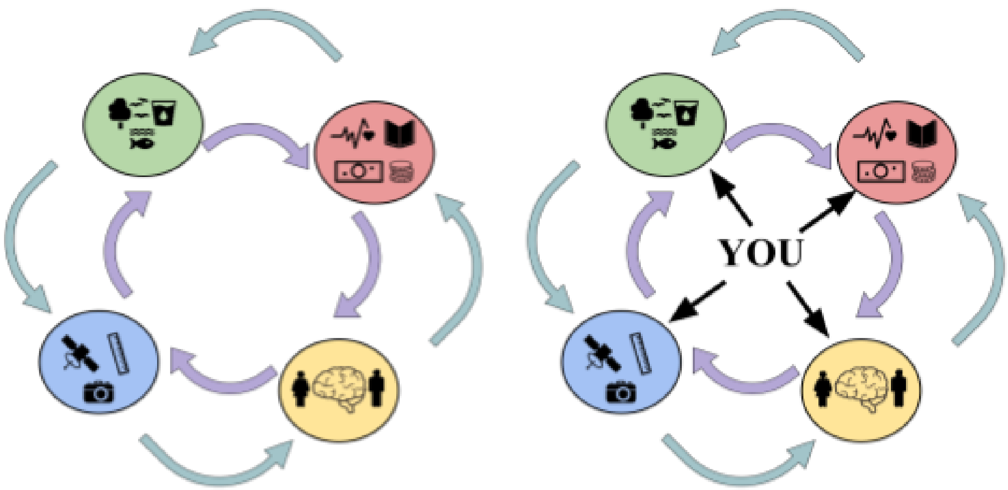

Figure 2: Simplified, stylized graphic showing the primary EVDT loop.

Figure 3 is a flowchart broken into two, color-coded portions. The bottom, green portion represents the primary artifacts and functions of a fully operational EVDT community. This includes the various back-end components, such as standards, code, and raw data, as well as various front-end components, such as the user interface and the applications for which EVDT is used.

The top portion, in blue represents the different forms of involvement and individual could take. I wish to emphasize that these categories are not necessarily distinct and one person could serve in both. This is particularly true for the Technical Area Experts and the Local Context Experts, which is why they are visually grouped together. These personnel categories are connected to the green portion of the flowchart at various points, indicating the artificats that they predominantely interact with. The blue categories are also interconnected with arrows moving from right to left. These indicate a potential recruitment pipeline. An individual may start off using the front-end interface to study some application of interest to them. They may then be encouraged to become more involved, serving as a local context expert and/or as a technical area expert, as their interests and background dictate. Then those with interest in improving the code and developing new functionality may become code contributors. Finally, those code contributors most invested in EVDT may become part of the core team (currently consisting of Space Enabled) that establishes standards and future direction of the project.

This diagram is intended predominantely for internal planning purposes among those already involved with EVDT (Space Enabled, other US team member,s international collaborators, etc.). Such a diagram could be made publicly available on the EVDT project website or the online code repository, as a means of communicating potential avenues of engagement. That said, the version shown below is likely what opaque to someone completely unfamiliar with EVDT and doubly so for someone with limited English. As a result, it requires explanatory text (such as that in the preceeding paragraphs) and/or significant revision to improve intelligiblity.

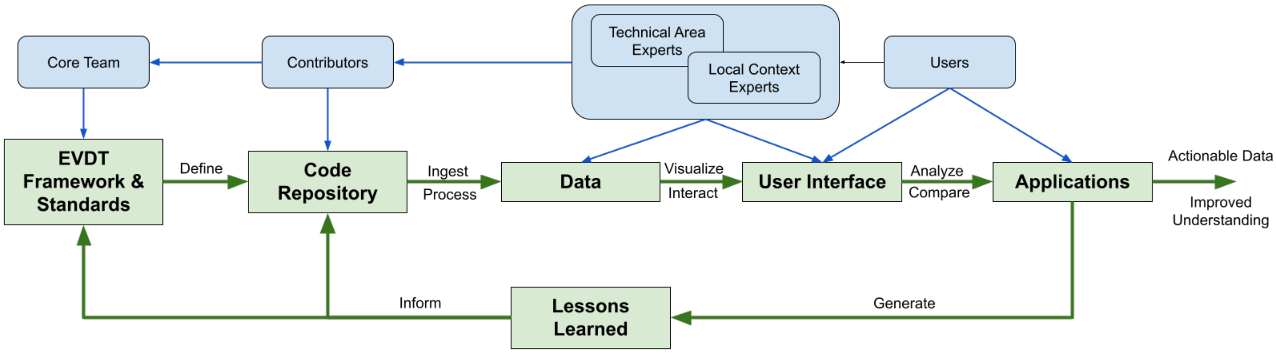

Figure 3: The EVDT development pipeline

Figure 4 is intended to communicate predominantely with interested researchers or expert users. It shows different possible configurations of the EVDT component models for accomplishing different research goals. These are not intended to be an exclusive list, but rather to illustrate the versatility of EVDT and inform potential future work. The first of these, Policy Design, most closely represents that of the current desktop version of Vida and is the one most likely to be used by government decision-makers. In this configuration, environment, social impact, and decision-making form a feedback loop, to which the user feeds policy choices and then receives feedback on impacts. The technology component, meanwhile does not take part in the feedback loop, but instead senses and reports on historical data, to better inform the users choices. Government officials and other community members could use this configuration to better understand the relative impacts of different policies and thus use it to identify preferred policies for which to advocate.

The second configuration, Technology Design, is the one most likely to be used by systems engineers. Once again, the environment, social impact, and decision-making are arranged in an automated feedback loop. The user interacts primarily with the technology model, however, providing preferences and constraints on the sensing technology architectures. The model then iterates and generates potential remote observation architectures that improve environmental and social outcomes. These could be arranged in a tradespace for the user to then explore and select desired options. Systems engineers could use this configuration, potentially as part of design workshops with community members, to identify a set of architectures to persue in more detail or to compare the relative value of a set of pre-identified architectures. The latter would be akin to an OSSE.

The third configuration, Socio-environmental Scenario Generation, is less about design than about exploration. In this configuration, various possible future scenarios, including environmental and social impact trajectories, sensing technology development, and decision evolution, are simulated under a set of different assumptions. This would enable the user to gain a better understanding of the relationship between the different EVDT domains and thus inform future questions, to perhaps be answered by one of the other configurations.

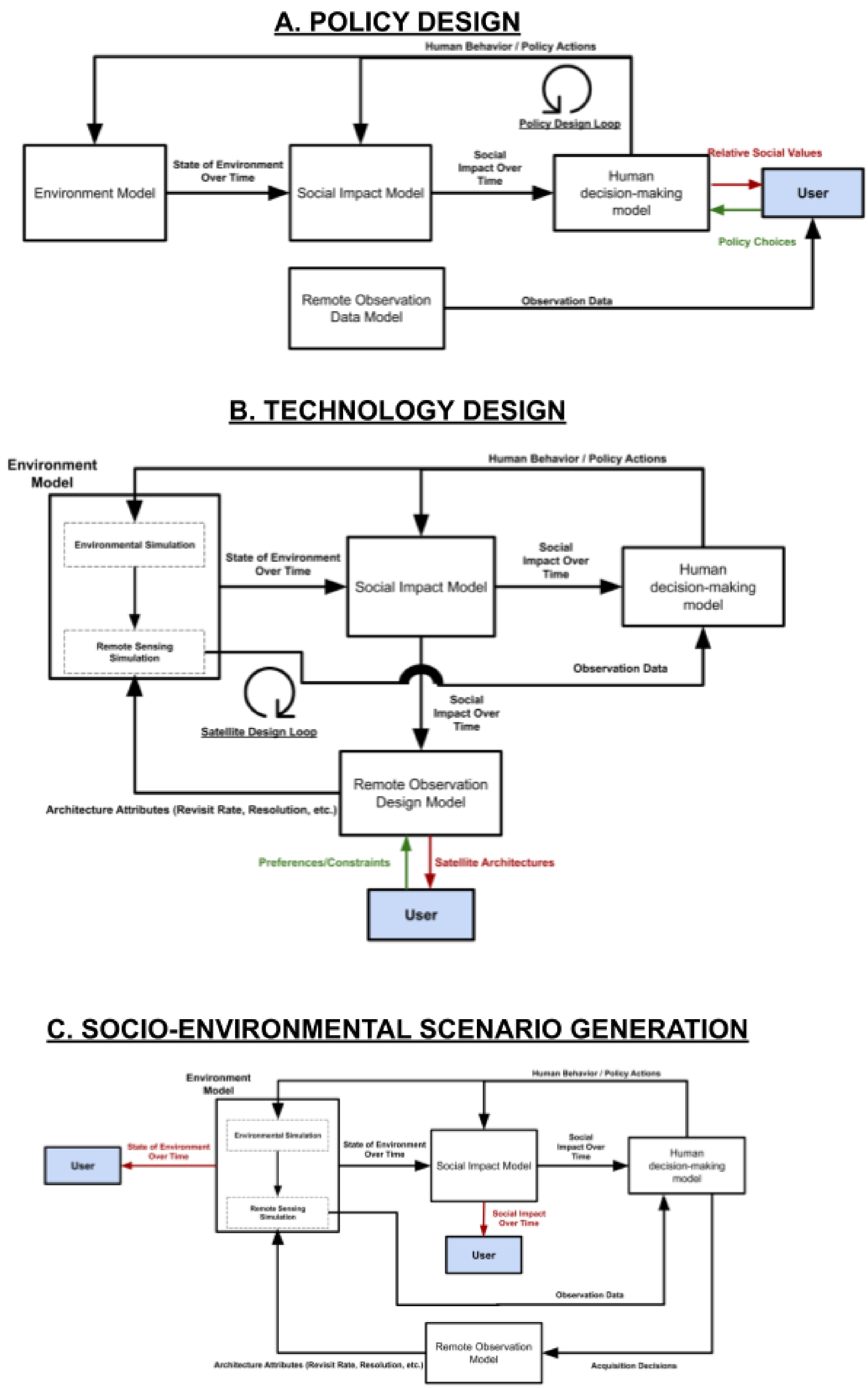

Figure 4: Three example EVDT research configurations.

5 Expansion Support

"**Start the process to explore what funding resources, community connections, collaboration and communication methods will support the vision you outline in item # 4 above.**"

One of the potentially frustrating paradoxes of interdisciplinary research is that it nominally qualifies for many more funding opportunities than research in a specific, narrow field, but in practice it faces difficulty in being scored highly in any particular funding opportunity, since it is not as specialized for that opportunity. Nonetheless, EVDT has been successful in getting funding thus far and is likely to continue to do so in the future. Funding resources are unlikely to be targeted at EVDT in general, but instead at various applications and uses of EVDT. Some of these include:

- Sustainable development applications, particularly those organized around the SDGs. Potential funding sources include development agencies such as USAID, the Inter-American Development Bank, and NASA's Applied Sciences Program; foundations; NGOs; and national governments.
- Targeted scientific research in particular domains, such as:
  - Environmental research (such as coastal mangroves), funded by NASA, NSF, or NOAA.
  - Remote observation system design and valuation, funded by NASA. Once demonstrated, national governments with new space agencies may be interested in funding such application to their needs.
  - Ecosystem services, funded by NSF or USGS.
  - Computing / modeling advancements, funded by NASA.

Some of the above are highly contingent on reputation and demonstrated results. For instance, national or local governments from around the world may be interested in commissioning studies of their local contexts, but are only likely to do so with specific examples of the intended end product. As a result, it is entirely possible that funding sources for EVDT will shift over time as it becomes more developed. In the meantime, the nature of EVDT is such that many potential collaborators will be able to provide in-kind contributions, particularly with their own time and expertise, as is the current case with many of our government collaborators.

As mentioned in Section 2, Space Enabled has a fairly high profile and already has numerous professional connections related to EVDT in academia, government, and other groups around the world. The latter should enable a certain 'snowballing' recruitment process, particularly if current collaborators end up pleased with the outcomes. The former helps provide a pipeline for completely new interested parties. It is quite possible that the primary issue will not be interest from potential recruits, but prioritizing the limited time and resources available to the Space Enabled team.

For this reason, should EVDT prove successful, it may prove necessary at some point to stand up a core governance team for EVDT that is related to, but separate from the Space Enabled team itself. This would enable the governance team to grow in size so as to better handle new recruits and the development pipeline. To a certain extent this has already occured, with researchers from other universities and organizations being involved in the core Vida team meetings. This would need to be formalized, with roles and responsibilities made clear.

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