A Participatory Planning Alternative for Mars Mission Design

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Abstract

This paper presents a Participatory Planning Alternative to traditional systematic method (Systems Engineering) approaches for space mission design in general and Mars mission design in particular. Traditional system engineering is inadequate to handle ill–defined problems such as "establish permanent human presence in space" because it does not address the enormous participatory complexity of such an undertaking. The Participatory Planning Alternative does address this dimension of problem–solving through two means: a Problem Participatory Complexity Factor Model and a Participatory Planning Process–oriented approach.

This Participatory Planning Alternative will enable the space program to ask the Big Questions about Mars exploration to better define and structure the Mars exploration problem. It will help develop appropriate design research objectives to select Mars mission technologies, architectures and criteria for evaluating Mars Mission designs. This alternative will also facilitate flexibility in the design of a participatory design process that can handle the design complexity of Mars exploration as including all the interested actors.

This paper compares the major points of participatory and systematic methods and shows why participatory methods are more appropriate to reduce complexity and to develop a well-structured problem definition. It offers several simultaneous models to comprehend the totality of the planning process.

INTRODUCTION

When I first talked to Chris McKay about this topic, I had the feeling that I might be a voice crying in the wilderness about the whole nature of participatory planning and the aspects of problem complexity that we would have to deal with in putting together a Mars mission at a national or international level. However, I have heard already many people here presenting attempts to grasp the organizational, participatory, and international aspects of a Mars mission as a design project. This common concern is heartening because it indicates that the Case for Mars conference is fertile ground for the ideas of research in design process that I will present.

This paper addresses the limitations of traditional Systems Engineering to handle the ill–defined nature of Mars exploration. This "problem" is quite vague, to "establish a permanent human presence in space." It involves enormous participatory complexity — design complexity. I will offer a comparative critique of participatory process versus systematic methods. This presentation distinguishes design complexity as distinct from technical difficulty. It suggests methods to attack that complexity by comprehending the totality of the planning process to make the design process explicit and consensus building rather than covert and divisive.

Second, I will present some aspects of the participatory planning as an alternative process. I identify several perspectives to understand for Mars mission design.

Program management becomes more difficult under conditions of great complexity. Often the institutional response to increased complexity is simply to increase the size of the organization, to match the unexamined problem. Organizational growth is valuable to cover specific technical content. However, for the unexamined problem of unreduced complexity, design organization growth quickly becomes bureaucratic bloating.

Nevertheless, design organizations must provide a forward-looking planning capability. The increasing tempo of the rate of change increases to need to plan.[1] Richard Duke describes managing under increasing complexity:

1. A future-orientation that implies that precedent and the lessons of the past are of limited value;
2. The lack of a clear paradigm for action, since no satisfactory model exists, either conceptual or pragmatic;
3. The need for a dynamic process for closure on organizational overview, an interactive process that deals with the widely varying perceptions of the many actors in the dialog.[2]

These problem management characteristics confront any design proposal to explore Mars. The intent of the Participatory Planning Alternative is to provide a basis for the necessary future–orientation, paradigm for action, and dynamic, interactive process for an international Mars mission design.

THE NATURE OF DESIGN PROBLEM–SOLVING

When I say that the problem confronting Mars exploration design is traditional System Engineering, I mean the misapplication of system engineering methodology to problems for which it is not appropriate. System Engineering succeeds for well–defined problems like “send a man to the moon and return him safely to the Earth.” That’s a very specific type of goal. But Mars? We want to go to Mars, to do something on Mars — figure out what it is — and we don’t know how long we’ll be there, and we don’t know the stopping point. Designers and planners will not find answers to these “wicked problems” through conventional system engineering methodologies.[3] As NASA and international space programs become more complex, I believe that system engineering methodologies will work less well to frame and decompose these problems.

Systems Engineering works well for solving well-defined problems of technical difficulty but it is not appropriate for solving ill–defined problems. The social or participatory complexity of design problem-solving is a completely separate dimension of problem–solving from technical difficulty. Reducing complexity requires moving the problem from an ill–defined or ill–structured initial problem state to a well–structured problem state.[4] Once the design team resolves this complexity they can apply systematic methods to the newly well–structured problem. **Figure 1** illustrates this distinction.

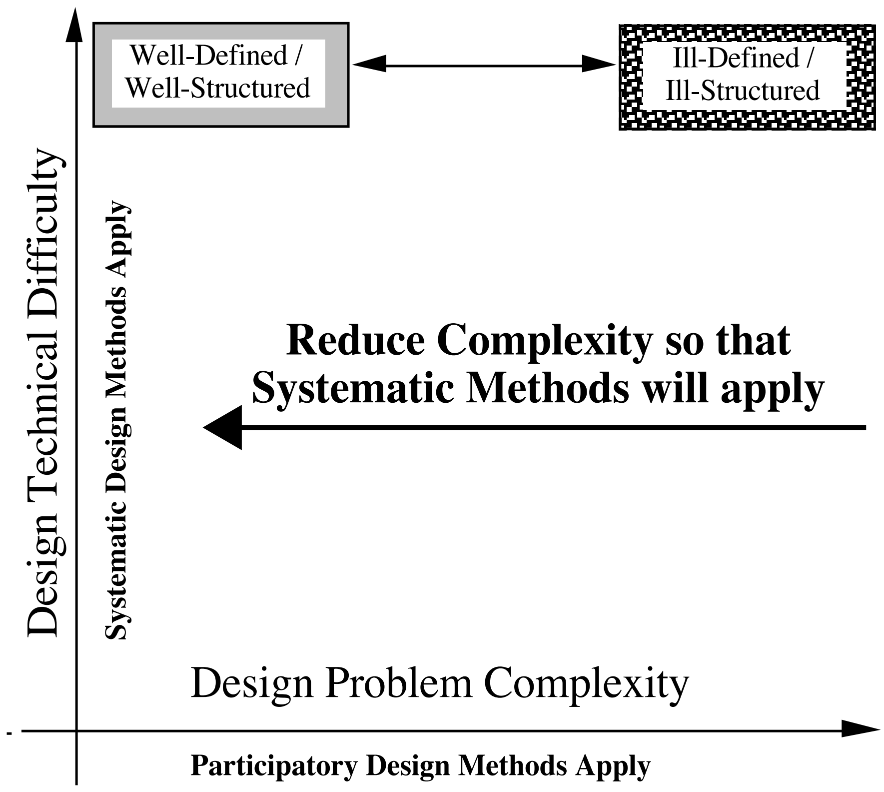

Figure 1. Diagram of Participatory Complexity vs. Technical Difficulty.

HAZARDS OF COMPLEXITY AND ILL–DEFINED PROBLEMS – A common error in developing major design projects is the failure to recognize the full scope of complexity and to find a way of managing it. This difficulty occurs in many design realms, including urban planning. The Dutch architect Aldo van Eyck observed this phenomenon in 1969, the year of the first moon landing, in a statement about urban planning that grew prophetic about the fate of America's investment in the Apollo program:

> But do we know – or are we prepared to acknowledge – that, whilst in the past societies responded more or less successfully to the problems limited number posed, ours, today, are no longer able to. Let alone able to respond to the problems — call them perplexities — vast multiplicity poses . . . .
>
> Whatever gain is made is soon counteracted by another gain, FOR OURS IS A SOCIETY OF WASTED GAIN. It is also one of bewildering technological ability. That is its familiar hallmark.
>
> But there is another hallmark – a less familiar one. Our pitiful inability to come to terms with greater number and behave with sanity toward the environment – that great place where each person and every people must live [original emphasis].[5]

It is quite credible to describe the US space program in the years following Apollo as "a society of wasted gain" unable to grasp the "vast multiplicity" of its potential future options. This situation continues in the space shuttle and space station programs. It impinges upon all the operational measures, including life–cycle costs, maintainability, reliability, safety and human productivity.[6]

Space Station Freedom is a case study of a design solution for which NASA never reduced this complexity, despite elaborate and extensive system engineering. NASA never converted from an ill–defined state to a well–defined state based upon a realistic knowledge of who will use the space station, why they'll use it and how they'll use it. Thus, this program continuously revisits every policy and design decision. For a decade, it seems the program cannot decide anything, and once they do decide, the decision has little or no staying power because of lack of consensus on the problem definition. It would be catastrophic to make a similar error for a Mars Mission.

SYSTEM ENGINEERING versus PARTICIPATORY PLANNING

This comparison argues not that one approach is better than the other but that they have different applications, origins, purposes, and strengths. In fairness, the high ideals of System Engineering that coincide with the founding of NASA.[7] As a profession[8], System Engineering provides a key to integrate technical systems [9] with their social and organizational setting[10]. When properly applied, System Engineering methods can produce better results than most designers usually attain without a systematic approach.

This critique does not concern the "best" System Engineering, but rather addresses the "lowest common denominator" practices that tend to occur throughout government and sometimes in industry. When design organizations misapply system engineering methodologies to problems of social complexity for which they are not appropriate, the outcome usually is a dismal product or project. Technical problem–solving efforts apply more smoothly and with greater clarity when non-deterministic complexities do not confound them.

This comparison of System Engineering and Participatory Planning is a summary of my observations of the two approaches in actual practice. The main points of comparison are requirement definition, problem structure, multiple claims, dividing the work, decision–making organization and decision–making sequence.

SYSTEM ENGINEERING –

1. SYSTEM ENGINEERING – ***Requirements Definition*** – The "First Commandment" of System Engineering is that the designer shall define all the requirements before beginning design synthesis. This precept prevents inefficiency and duplication of effort and helps ensure that the project builds only the "right technology." This penalty derives from not having sufficient data from which to attempt a design solution, but not recognizing this shortcoming and calling the available information the "requirements."

2. SYSTEM ENGINEERING – ***Problem Structure*** – The work–breakdown structure in systematic methods always assumes implicitly that the problem is well–structured. If it not well structured, the situation will follow the space station scenario, where the design management revisits the key decisions again and again, but never approaches an optimal solution.

3. SYSTEM ENGINEERING –***Multiple Claims*** – Systematic method–oriented project management views multiple claims on the work as a redundancy and a source of conflict. Most system engineering managers will immediately try to divide the work between various groups so that they can work most efficiently and not overlap. This imperative to snuff out competing — and creative — ideas for the sake of "clean interfaces" leads to the unprincipled and unprofessional politicization of the design process. The design organization with the most political clout wins the discussion — not the best design solution.

4. SYSTEM ENGINEERING – ***Dividing the Work*** – Design managers divide the work quickly to match the existing organizations and their norms. Rarely is it possible to make this kind of division, a priori, without missing some key elements. In many NASA projects, there is the period of rude discovery, when the items omitted in the rush to divide the work reappear. Some design managers discover that they are responsible for pieces that they do not want, but that other design groups "own" pieces that they need. This game of dealing a

hand of design responsibilities makes the quality of the design depend upon the ability of design managers to play poker, not their ability to design or deliver a good product.

5. SYSTEM ENGINEERING – ***Decision-making Organization*** – Hierarchical decision–making favors "most rigorous" solutions but tends to ignore more appropriate problem definitions because they are less amenable to rigorous solutions. Rather than recognize complexity and grapple with it, the design decision-makers tend to map the design problem onto the existing organizations. Thus, by making the design solution look like the status quo, business as usual ensures that innovation cannot succeed. This tendency often occurs more for bureaucratic convenience than because of any profound understanding of the design problem definition.

6. SYSTEM ENGINEERING – ***Decision-making Sequence*** – The hierarchical imperative leads to a serialization of the design process. Systemic decisions force other decisions, but rarely is it possible to evaluate each on its own merits. Often, the politicized division of work means the withholding of vital information with dire consequences for design quality. The design bureaucracy dictates a structure and sequence of review boards and advisory panels that obscures rather than clarifies both the technical content and the design solution for that content.

PARTICIPATORY PLANNING –

1. PARTICIPATORY PLANNING – ***Requirements Definition*** – Research in design process is a tool for defining the design problem and the requirements for its solution. If the Mars exploration initiative expects to define all the critical requirements by some particular date, the participants will never agree at any date. The purpose of the participatory planning process is to arrive at the design requirements through reasoning, rather than to start from requirements that a manager (with no accountability for the product) established a priori.

2. PARTICIPATORY PLANNING – ***Problem Structure*** – Participatory process involves all the concerned parties in a consensus–building approach to define the problem, and this consensus–building is a large part of what the Case for Mars is doing. It is essential for the project participants at all levels to share a clear vision encompassing the design problem definition and structure

3. PARTICIPATORY PLANNING – ***Multiple Claims*** – Multiple claims occur when several parties want to contribute to the same portion of the design work. It is advantageous to encourage multiple claims to the work to find higher levels of common interest and cooperation. The collaboration of the Planetary Society with the Soviets and Europeans on the Mars balloon mission is an

excellent example of how this kind of synergy can work. Multiple claims do not constitute a threat to management control, but indicate a potential to achieve a higher level of design synergy.

4. PARTICIPATORY PLANNING – ***Dividing the Work*** – Instead of using each new project to replicate the existing organizational culture, the participatory process would allow the actors to reconstitute the organizations to match the problem structure. This approach would allow the organization to cover a greater range of options, prevent some elements from "falling through the cracks," and avoid prejudging technical options because of existing preferences.

5. PARTICIPATORY PLANNING – ***Decision–making Organization*** – The "Symmetry of Ignorance" recognizes the value of each participant's contribution[11] — both ignorance and expertise occur across all participants. This mutual respect is a basis of democratic decision–making to seek the best problem definition. The long term goal is to achieve a consensus on the problem definition and the requirements that follow from it, sustainable for the project life cycle.

6. PARTICIPATORY PLANNING – ***Decision–making Sequence*** – The recognition of decision interconnectedness allows parallel and interactive decision processes, based upon the sharing of information. In regarding design as a research process to develop requirements and criteria, the parallel process leads to explicit decision-making that considers all the relevant information, not just conveniently compartmentalized information. This decision process does not simply "trade everything against everything else forever." Instead, it seeks the reduction not the propagation of complexity.

DESIGN PROBLEM DEFINITION

The differences between space mission planning and the other types of problems solving are subtle but important. The three main points of difference are the long duration character of a Mars mission, the evaluation of competing solutions and the implicit design character of space mission planning.

Beginning from a Condition of Irresolution –

Designing is not necessarily an act of problem-solving. Winograd and Flores argue that much design activity does not start from a specific problem, but rather in a "condition of irresolution."[12] The familiar pressures — to find solutions to immediate terrestrial problems such as pollution, economic revitalization, or starvation — do not apply to Mars exploration. Although the goal is to mount an expedition to Mars, it is not admissible to argue, "the problem is" that humankind lacks a human Mars mission.

Thus, the USA and international space programs start for Mars from a condition of irresolution.

Choice makes the difference between designing to solve problems and the designing for irresolution is choice. The participants in this undertaking all choose to play a role and they choose the degree to which they become involved. The Case for Mars is important not because of a need to go to Mars but because of the choice to go to Mars. Thus, the consensus in support of a Mars Mission must grow from common choice rather than from common necessity. This choice and this consensus may produce a new freedom to create mission designs that break the mold of business as usual.

<u>Competing Problem Definitions</u> – The space-faring nations who go to Mars will choose among competing design problem definitions and solutions. Despite the broadest consensus over the goal of human Mars exploration, many differences will emerge among the supporters of each mission strategy. The tough decision will be choosing between these mission architectures and strategies. The ability to evaluate the design complexity of the design approaches from the outset will prove extremely valuable.

<u>Evaluation of Design Solutions</u> – Mars exploration differs from other design endeavors in one significant aspect. Every possible problem definition or project proposal seems to arise from a potential design concept or solution, and remains linked to it. Nonetheless, it is vital to make the problem definition stand on its own and to separate it from the pet "hobby shop" projects that become attached to them.

Well-established engineering assessment techniques are available to evaluate Mars mission architecture upon its technical merits. The participatory complexities of these mission architectures demand a clear, consistent, credible and fair evaluation method.

REDUCING PROBLEM COMPLEXITY – Designers use several approaches to reduce problem complexity to a well–structured state. I identified three broad avenues; business as usual, transforming events and research in design process. Business as usual is the most common. Both transforming events and research in design process are rare.

<u>Business as Usual</u> – Reorganizing is the favorite mode. Most management equates a new initiative with a new reorganization. Other modes involve changing the names or changing the goals of the organization. Often, new management implements new procedures, creating the appearance of change, but the fundamentals remain the same — even though some people do different jobs. Often, the design management maps the design problem onto the existing organization so that it looks like everything else they

have done. Next, the design organization may expand itself to match the assumed complexity but without ever questioning or reducing it to a good problem definition.

Nothing succeeds so well to justify organizational expansion — more facilities, funding, people, positions, and power — as an excessively complex problem definition. Thus, in a bureaucratic environment, all the incentives occur on the side of a bad approach to solving the problem. There are no rewards for finding a solution for lower cost or with fewer people.

Transforming Events – Transforming events include leadership, radically new design concepts, scientific breakthroughs, and new technological developments. Scientific and industrial revolutions may grow from a single innovation such as the transistor led to the information revolution. Often some transforming event or combination of events is essential also to a successful major program, such as Mars Exploration. Transforming events are great when they occur, but they are difficult to predict so that it is not possible to rely on them or upon the expectation that they will occur.

Large design bureaucracies excel at stifling innovation, which always threatens their primacy. The enabling role of technology often gets lost among the political quid pro quos of large programs. If the group that controls a particular portion of the design is the group that developed the most innovative solution, it's Not Invented Here city.

Research in Design Process – The traditional attitude toward design is that the result, the product, is most important and that how one reaches that result is of secondary importance. Karl Popper reflects this attitude in arguing that the problems of produced structure are as a rule more important than the problems of production.[13] To the final user, this emphasis is correct and necessary. However, the designer must devote substantial attention to how he or she develops both the design problem definition and the solution to it, to ensure and enable future invention and innovation. This attention to the means is research in design process.

Process versus Product – Research in design process differs from research in design products. An appreciation of this distinction underlies the Participatory Planning Alternative.

Research in design product involves creating performance measures and requirements for the design outcome. This testing and evaluation are essential to ensure safety, reliability, quality assurance, and operational performance. However, these performance measures are primarily prophylactic — they seek to ensure performance by preventing error. They cannot ensure good design solutions or foster new approaches to designing.

Research in design process involves developing new theoretical understandings of design, new decision making processes, and new design planning processes for new types of projects. How a designer designs signifies as much as the requirements he tries to accommodate. How the designer interprets those requirements, how he responds to them, how he synthesizes those responses all affect the design outcome. Each new design project — or new class of projects — demands research in design process. The designer must inquire what is the best approach to that specific design challenge.

THE PARTICIPATORY PLANNING ALTERNATIVE

Given the preceding comparative analysis of the systematic and participatory planning approaches, it is possible to state the participatory planning objectives for a long range Mars exploration program.

PARTICIPATORY PLANNING OBJECTIVES –

1. Understand what we want to achieve on Mars and determine the best way to do it.

2. Comprehend the relative advantages of human versus unmanned Mars exploration modes and formulate the most beneficial combination of those capabilities.

3. Define the critical life science, habitability, crew resource, work, and human performance requirements.

4. Identify the vital architectural design concepts and technology for working and living, IVA and EVA.

5. Develop an on–going architectural design research activity to support exploration opportunities.

MARS MISSION PLANNING: THE BIG QUESTIONS – By conceiving of the planning process as a design research activity, it becomes possible to ask the "Big Questions" about Mars mission selection and design. These questions cover the comparative advantages of the different possible modes of exploring Mars and the impact of international participation on exploration strategy, technology, and infrastructure choices.

Mars Reconnaissance – What is the best mode for a general reconnaissance of Mars to pursue scientific exploration and to prepare for a permanent Mars Base? This question includes the issues of Mars sample analysis in situ versus Mars sample return. It focuses all the potential strategies for machine exploration such as an autonomous rover, remote sensing by satellite and a teleoperated probe or rover.

Mars Site Examination and Selection – Does a manned reconnaissance mission offer any advantages over unmanned site examination for selecting a Mars Base site? What would be the survey requirements for topographic mapping, soil borings, preliminary excavations, and tests of soil bearing capacity? What measures would be important for local environmental monitoring and the interpretation of monitoring data?

Human Mission Approaches – Does a "Sprint Mission" of about 30 days on Mars offer any advantages over a permanent manned Mars Base approach as a first manned mission? How do the investments in research, development, tooling, and training compare for a throwaway versus a permanent mission approach? Given the ability to support a round trip Mars mission of at least 500 days, what is the total cost increase for beginning a permanent manned Mars Base on the first manned mission?

Impact of International Cooperation – How will international cooperation affect the Mars exploration choices? Each of the potential international partners — ESA, Canada, USSR, and Japan — can offer their special strengths in technology development. Technology development drives new design solutions. How will the Mars planning process choose among the many international options? Would American companies or agencies agree to cooperate with technology development efforts in other countries?

PARTICIPATORY PLANNING ALTERNATIVE - This approach takes a long view of Mars exploration. It assumes the validity all scientific, habitation, human performance, and resource production questions. These questions deserve consideration on their merits and the Mars exploration program needs to comprehend the relationship between them. This approach emphasizes Mars missions to support science. A key to this comprehension understands the interaction of the scientific objectives; human performance capabilities and Mars mission architectures.

What most distinguishes the Participatory Planning Alternative's Approach is that it "solves the problem backwards." The traditional method starts by estimating how much payload is reasonable or economical to deliver to low Earth orbit, then to Mars and then to Mars orbit. The participatory planning approach asks first: what does humankind want to know about Mars? Then, what is the best way to learn it? What are the exploration requirements to acquire this knowledge? What capabilities must the Mars mission deliver to the Mars surface? Once the mission planners make these determinations at a consensus level, they can communicate this well–defined problem set to the System Engineering disciplines to design mission hardware.

DEVELOPING THE PARTICIPATORY PLANNING PROCESS – Developing the participatory planning process as a research tool allows designers to recognize the multidimensional nature of these planning activities. These dimensions constitute varying ways to describe the multifaceted attributes of the Mars mission planning process. Ivo Wenzler outlines three "schematics" to describe graphically a problem and its context:

1. Schematic by relationships between actors
2. Schematic by roles
3. Schematic by process flows[14]

To these three schematics, I have added two others:

4. Schematic by logic of design and technology development
5. Schematic by alternative paths

Each of these schematics presents a perspective on decision–making with to comprehend how the entire process works. Often people who study or employ decision–making processes concentrate on only one of these aspects. Consider design as a polydimensional decision process. These separate snap shots of the planning process and the relationships between these views comprise its totality.

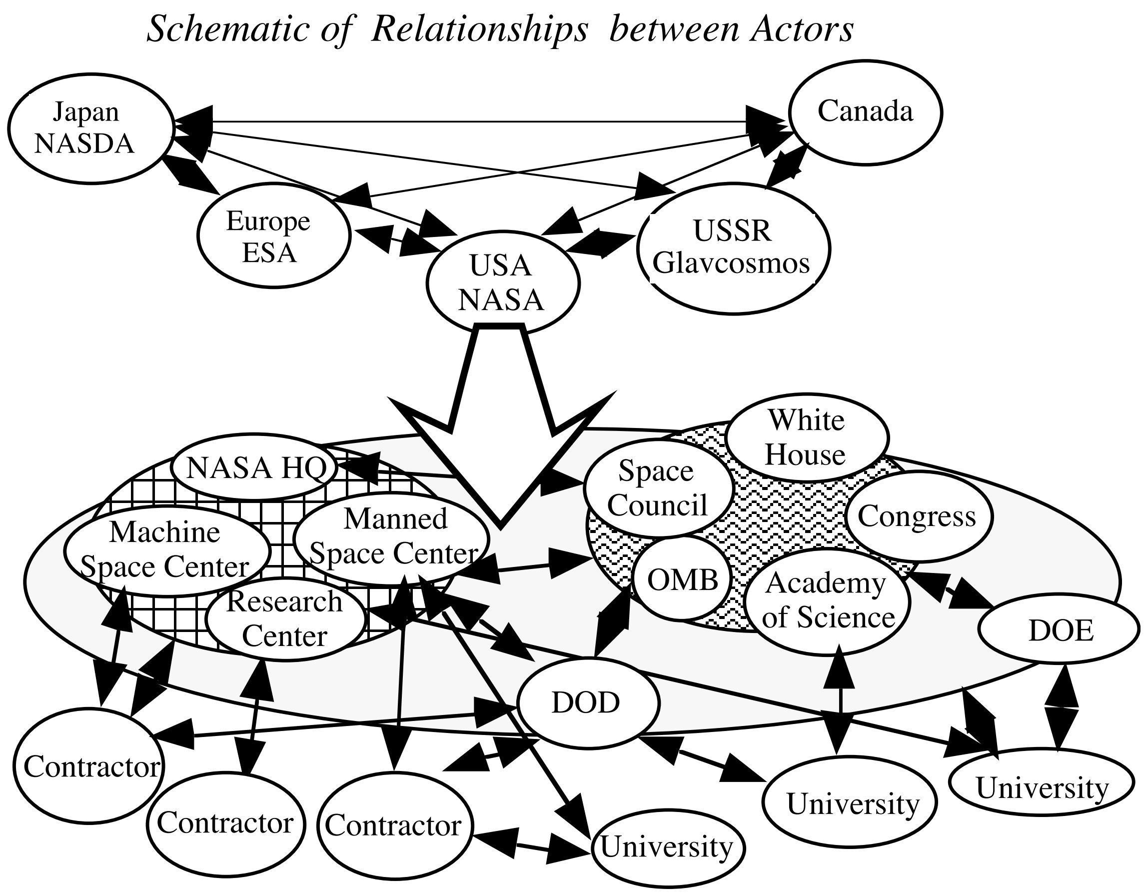

Figure 2. Schematic of Relationships between Actors in Mars Exploration Planning

<u>1. Schematic by relationships between actors</u> – **Figure 2,** represents cooperation as a set of relationships between the organizations involved in space exploration. Everyone who has worked in a large organization has seen this kind of chart. Otto Steinbronn of General Dynamics presented a strawman international organization for Mars exploration in this vein, modeled on ESA.[15] This schematic of relationships illustrates the major national space programs, with a zoom–in on the US space program to show the network of relationships at work between NASA and other federal actors, industry and academia. This schematic reveals a static nature, which tends toward a self-consuming inertia.

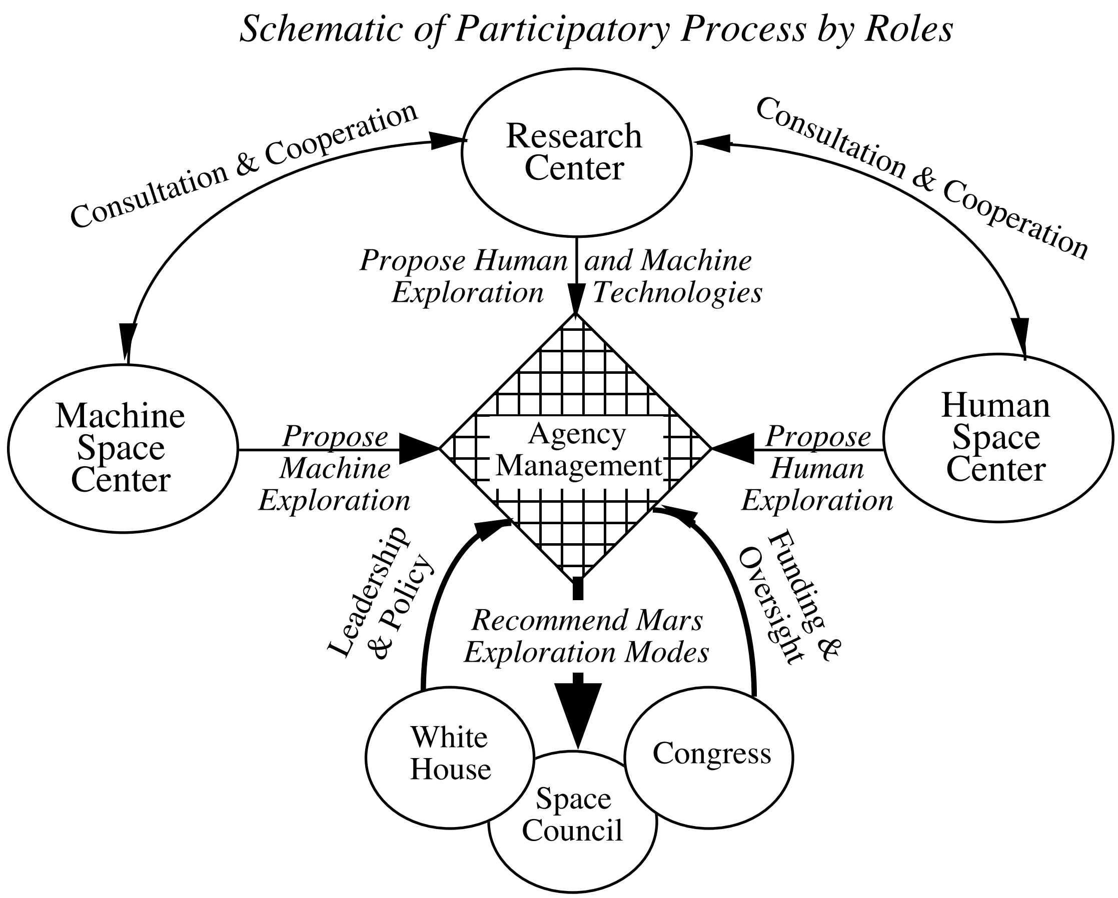

Figure 3. Schematic by Roles between Actors for Mars Exploration Mission Planning.

2. Schematic by roles – Figure **3** represents the interaction of several groups by roles. In this model of exploration roles, there are two three performing organizations: for human exploration, machine exploration, and technology development. Agency management provides a decision making function, evaluating and recommending or selecting the appropriate design problem definitions and design solutions. This schematic reflects the traditional attitude insofar as it displays a hierarchical relationship. However, this schematic inverts the political hierarchy to emphasize the design roles and responsibilities. Regardless of the politics of the moment the design, responsibility resides with the technical expertise. To do otherwise limits the participants' roles and wastes the designers' time by over-constraining or biasing the design results.

However, this schematic conveys a system insufficient by itself to ensure the best design. For example, this approach would continue to allow NASA to emphasize optimistically low initial cost projections over a life cycle approach. On the other hand, it highlights the importance of building a consensus upon a design problem definition and solution strategy that the entire agency can support, sustain, and deliver as promised.

3. Schematic by process flows – **Figure 4** shows the schematic by process flows to develop Mars exploration requirements. It portrays three major goals: Mars Science, Human performance, and Space Architecture that translate closely into advocacy constituencies. These advocates define what scientific missions to do, what human or unmanned performance characteristics and capabilities would best accomplish them and what architectural design features would best support a crew on Mars. For example, the Human Performance Group would advise the Science Exploration group what human capabilities might be best for a particular exploration objective. The Science Exploration Group would respond, by selecting an exploration strategy; either human or machine, and if human, how many crew members, with what skills, for what time. If the Science Exploration group chose a machine exploration mode, they would decide between the choices of telepresence, remote sensing, or an autonomous rover.

4. Schematic by Logic of Design and Technology Development – Figure **5** continues from the "Define Mars Mission Requirements" box that concludes Figure 4. Now the goal is to translate those requirements into capabilities to deliver to Mars. This schematic shows 3 key milestones: the Mars Mission requirements definition derived from Figure 4, the decision to conduct full Mars mission planning on an iterative, ongoing basis, and the implementation of the Participatory Planning Alternative. This logic presents quasi-symmetry between the top and bottom halves, divided about the center axis, anchored by the Mars Mission Requirements. However, there is a significant difference: the NO path on the lower half returns the mission plan to defining capabilities whereas the NO path on the upper half forces the planners to reexamine the mission requirements.

This schematic shows that there are three central decisions that can make the Mars Mission planning process succeed or fail, and all of them require a positive outcome. These decision loci lie along the axis of symmetry: *Define the Capabilities to Deliver*, *Plan the full Mars Mission,* and *Build a Consensus* upon the design problem definition and its solution set.

If NASA decides against a full Mars mission planning effort, it fails to provide the fundamental rationale for exploration technology development. The lack of a clear purpose for exploration inhibits the integration of technology development with advanced mission planning. The cost of failing to resolve these key decisions positively will increase the mission cost in effort, expense, time, and uncertainty.

If NASA decides to plan a full Mars mission, it becomes a global driver, creating the possibility of positive outcomes to follow. These results include: developing an integrated technology approach, building a consensus upon the Mars Mission design problem and solution sets and to coordinate multi-Center design efforts.

5. Schematic of Alternative Paths – Figure **6** shows the Alternative Paths to Mars, flowing from the Scientific Exploration Requirements to the Mars Mission Architecture options. Given the Science Requirements (line 1), two choices follow: manned or unmanned exploration (line 2). From these choices, there are three "classes" of mission, including a Buzz Aldrin type cycler (line 3)[16]. The alternative paths approach distinguishes these mission classifications from the mission architecture (line 5) to separate the temporal design questions from the flight hardware; when to start, how often to go, and when to return.

Between the mission classes and mission architectures, appear the degrees of participatory complexity (line 4). Four alternatives seem reasonable, although there isn't any compelling reason not to identify three or five participation options. Given certain scientific and temporal goals, the international Mars exploration participants would need to choose among these options as part of the planning process. It would not make sense to design mission architecture first and then try to divide it among all the international and domestic participants.

This schematic suggests iterating the alternative paths many times to find an optimum fit of Mars exploration goals and the means of achieving those goals. This mapping of alternative paths provides a boundary to the problem complexity on one page. It suggests a first order evaluation of path number as 5! = 120. However, Larry Lemke of NASA–Ames Research Center argues that there are really just two Mars mission architectures: Moon first or Mars first. "Mars first" yields a first order path number of 2*4! = 48. If the Moon does sit on the critical path to Mars, it gives a path number of 4! = 24.[17] This view coincides with Krafft Ehricke's statement that, "If God wanted man to become a space-faring species, He would have given man a Moon."[18]

CONCLUSION

A participatory planning approach is vital to future space exploration so that mission planners can better handle design complexity. The fundamental benefits of the Participatory Planning Alternative are to achieve a good design problem definition, to reduce the complexity of the design problem and to arrive at mission requirements with strong rationale and traceability. The Participatory Planning Alternative does not start from a priori requirements but from a set of general goals. It embodies a set of iterative processes including design problem definition and solution seeking to build a sustainable consensus upon the purpose of an exploration mission. To build this consensus, the Participatory Planning Alternative frames a set of schematics that attempt to comprehend the various perspectives and aspects of this undertaking.

Problem–solving in the realm of participatory complexity involves converting the problem from an ill–defined to a well–structured problem state. The Participatory Process presented above constitutes a candidate approach to moving the problem to a well–structured state to which designers may apply systematic methods to attack issues of technical difficulty.

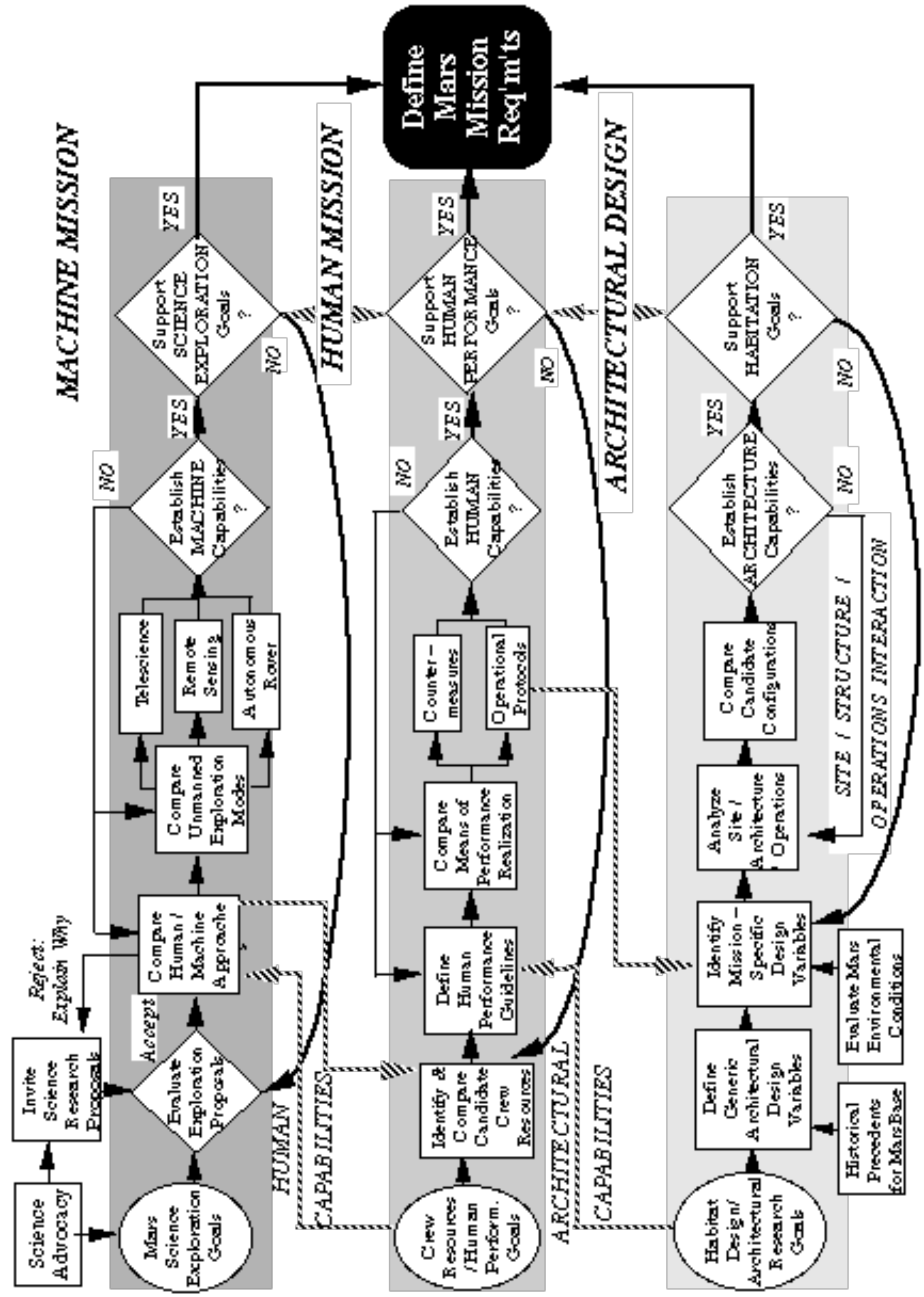

Figure 4. Schematic of Mars Mission Requirements Planning by Process Flows.

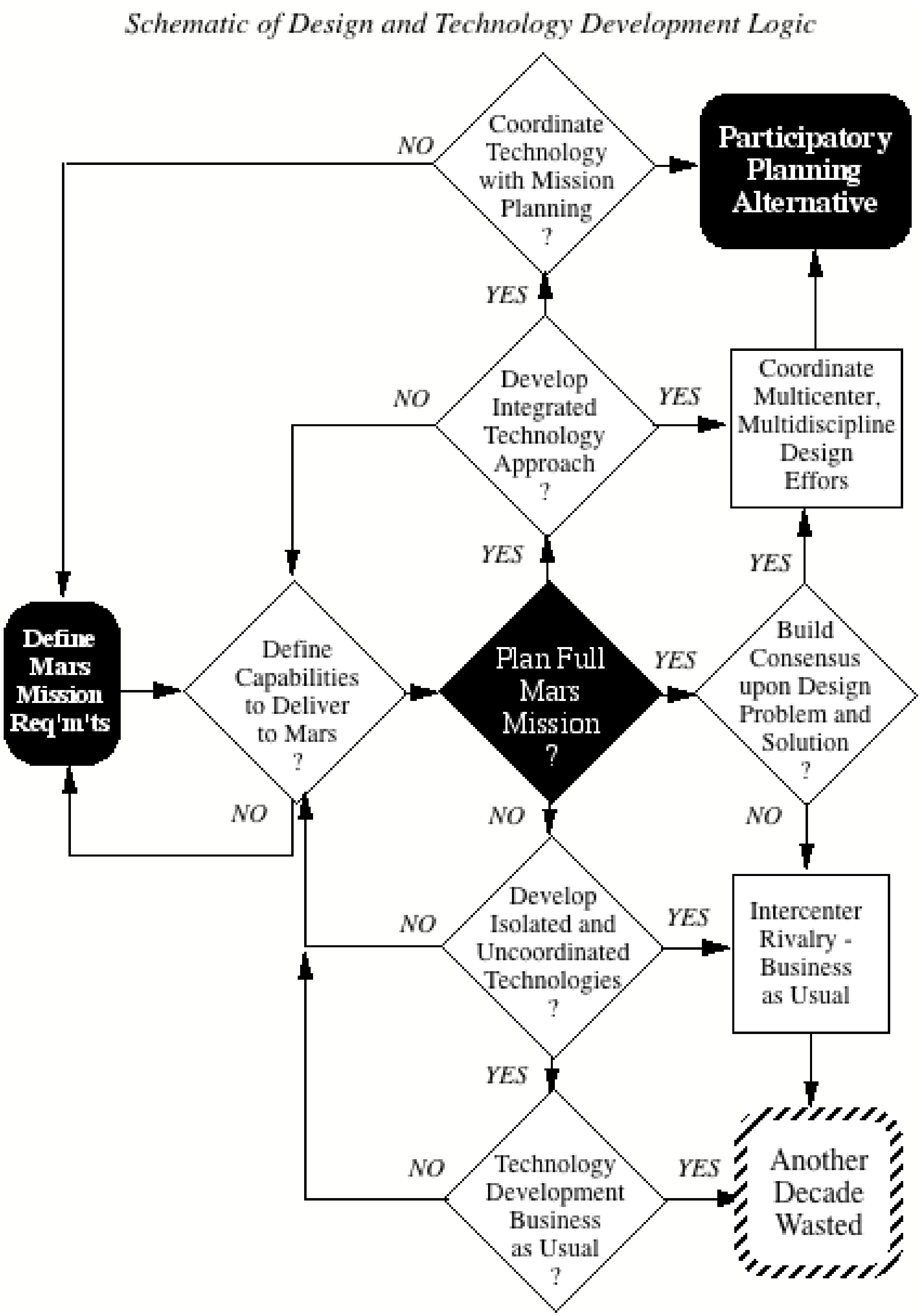

Figure 5. Schematic by Logic of Design and Technology Development.

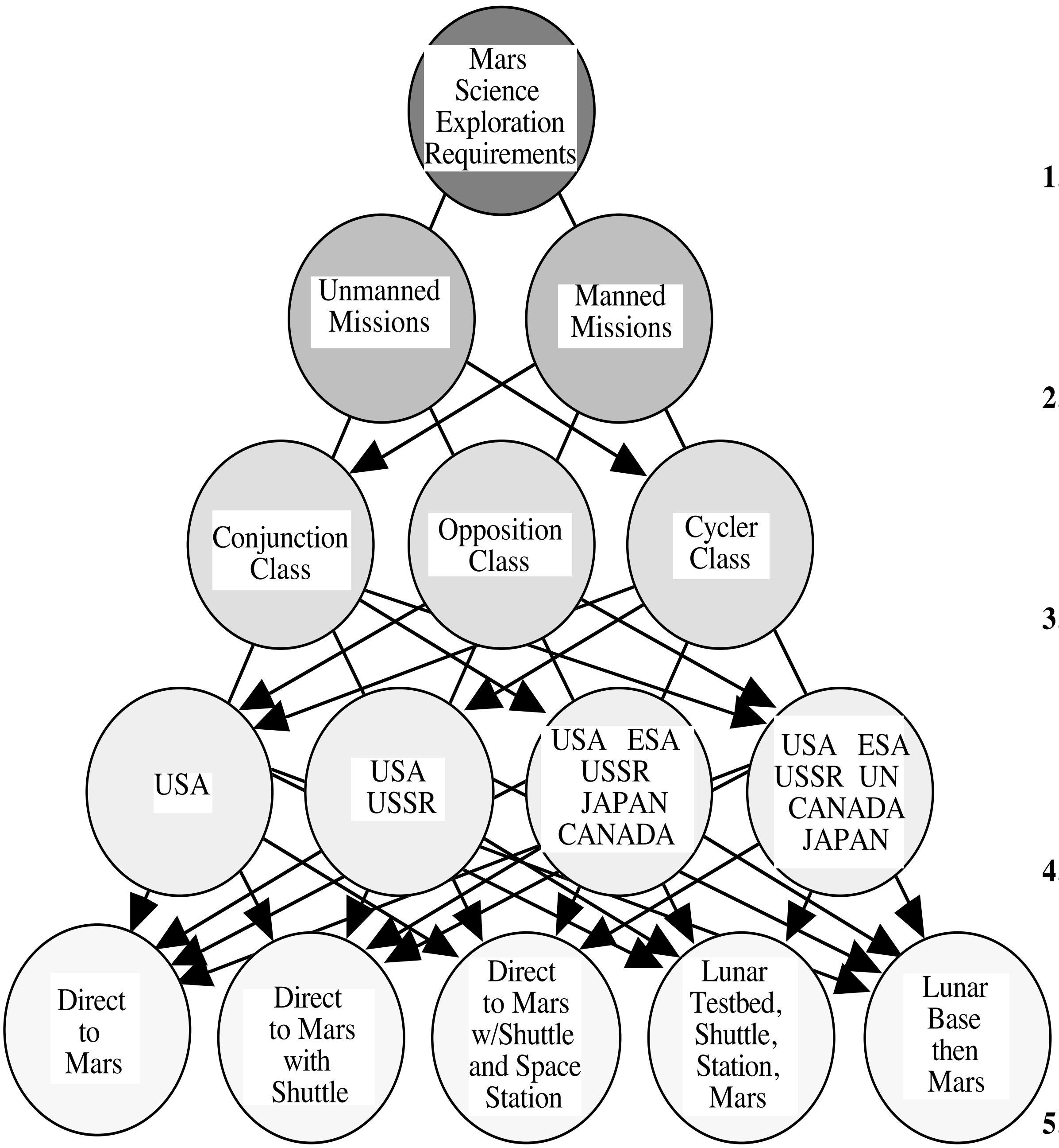

Figure 6. Schematic of Alternative Paths to Mars. These Mars mission architecture options illustrate the "vast multiplicity" involved in planning a human Mars exploration.

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