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TECHNICAL PROGRESS REPORT  
TECHNOLOGY MATURITY ASSESSMENT METHODOLOGY  
SDIO SYSTEMS SETA

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## Technology Maturity Assessment-Methodology

### 1. Introduction

A development program can be described and evaluated by three interrelated parameters: cost, schedule, and technical performance. These parameters can be visualized as the x, y, and z axes of a three-dimensional space. A program's desired objective, usually represented by a conceptual design, is a point in the three-dimensional space defined by the estimated or target values for cost, schedule, and desired technical performance of this conceptual design. To reach this goal, a series of events is laid out which defines the development path. Each event contains its own cost, schedule, and technical performance characteristics. Ideally, the summation of the individual event parameters equals the whole. It is impracticable, if not impossible, to condense (most programs to a single cost, schedule, and technical performance parameter. However, it is often possible to condense ) myriad development activities into a series of key activities and events which provide a reasonably accurate depiction of the overall program.

Because of the uncertainty of predicting the outcome of future events, almost from the moment a program is baselined, programmatic forces tend to impose changes on the baseline parameters. This is especially true of research and development programs, like the Strategic Defense Initiative, where many projects are pushing the frontiers of science and technology. However, all but the purest of R&D programs have a vision of the desired product; for SDIO-it is a ballistic missile defense system. Although there are usually many paths to reaching this end product, there are not an infinite number. Since changes to the baseline program are practically inevitable, the challenge to the program manager is to ensure that the program remains on a path leading to the desired product.

In practice, changes force the program manager to examine trade-offs involving the three basic program parameters. In order to perform effective trade-off analyses, the manager must understand how each alternative impacts planned development. Much effort has been invested in tracking and analyzing cost and schedule parameters. This is evidenced by the DODD 7000 series directives requiring cost and schedule tracking systems for major Government contracts. Cost and schedule management has its own set of terminology (i.e., Budgeted Cost of Work Performed, Actual Cost of Work Performed, Estimate To Complete, etc.) Unfortunately,

technical progress reporting has not reached the same level of standardization, automation, or definition.

The RRI team approach to evaluating SDIO technology performance proposes condensing the technical status of individual programs to a manageable number of categories and assessing the status using a standard framework. This is accomplished by building on the technology maturity assessment work previously performed within SDIO. This methodology has the additional advantage of allowing for a more uniform integration of technology data with associated cost and schedule data.

## **2. History of SDIO Technical Maturity Assessment**

SDIO has attempted to define technical maturity before. Borrowing from NASA and the aerospace industry, technical maturity was divided into ten levels progressing from an initial conceptual stage to deployment. The problems with this approach were, generally, threefold. First, it was a standalone depiction that did not tie maturity to a well defined system development framework. Second, the levels were defined at a very general level and could not be readily applied to the diversity of programs within SDIO. Third, program managers were left on their own to determine exactly how their program fit into the maturity levels. This created a large variety of interpretations of where program events fell on the maturity scale.

The RRI team approach to addressing these shortfalls is to use the DOD System Lifecycle Development process, or DAB process, as the framework for SDS development. The basic steps of our approach are summarized below:

- Map the existing technical maturity level definitions into the DAB process
- Expand those definitions from the top down and from the bottom up. Top down expansion ensures that the definitions are appropriately influenced by the presence of key policy and decision making issues. Bottom up expansion ensures that SDIO program managers can effectively map their program events into the definitions.
- Map existing data (e.g. from the Program Master Plan) on individual program development issues into the appropriate maturity level. The issues should be traceable to system requirements and expressed in engineering units of the required technical parameters (e.g. megawatts, km/sec, micro-radians, etc).
- Use the program control personnel in each of the deputes to assist the program managers in the mapping process. This will

ensure consistency in interpretation. PMA tasks should focus on efforts that increase technical maturity.

- Perform project risk analysis in the context of the cost, schedule and technical risks associated with progression from one level of maturity to the next within the given budget, schedule, and existing project configuration.

- Refine overall connectivity as the dependencies and barriers for moving from one level to the next become apparent.

## **2.1 Mapping Technical Maturity Levels Into The DAB Process**

Table 1 depicts the mapping of the technical maturity levels into the DAB process.

## **2.2 Expand the Definitions**

The DAB process is the DOD-accepted structure for systems development and acquisition. However, due to SDIO's political visibility other factors beside the typical acquisition issues influence the program. Conceptually, this effect is illustrated in Figure 1. The pyramid represents the presence of a few key policy level issues and directives that flow down to the program while the more numerous program-specific development issues flow up. The SDS program lies in the middle and the SDIO Director and staff work to balance the development program to ensure that the top down issues are adequately addressed and accommodated with full consideration of the reality of the technical issues that flow upward.

Time is a common factor to these processes. For example, many of the top down directives are tied to dates, e.g., a Presidential decision in 1992/1993, deployment timeframe, ABM Treaty compliance until 199X, etc. The bottom up technical development issues are tied to time by the reality of what can be accomplished in a given period with a given budget. Finally, the DAB process is basically a chronological development methodology.

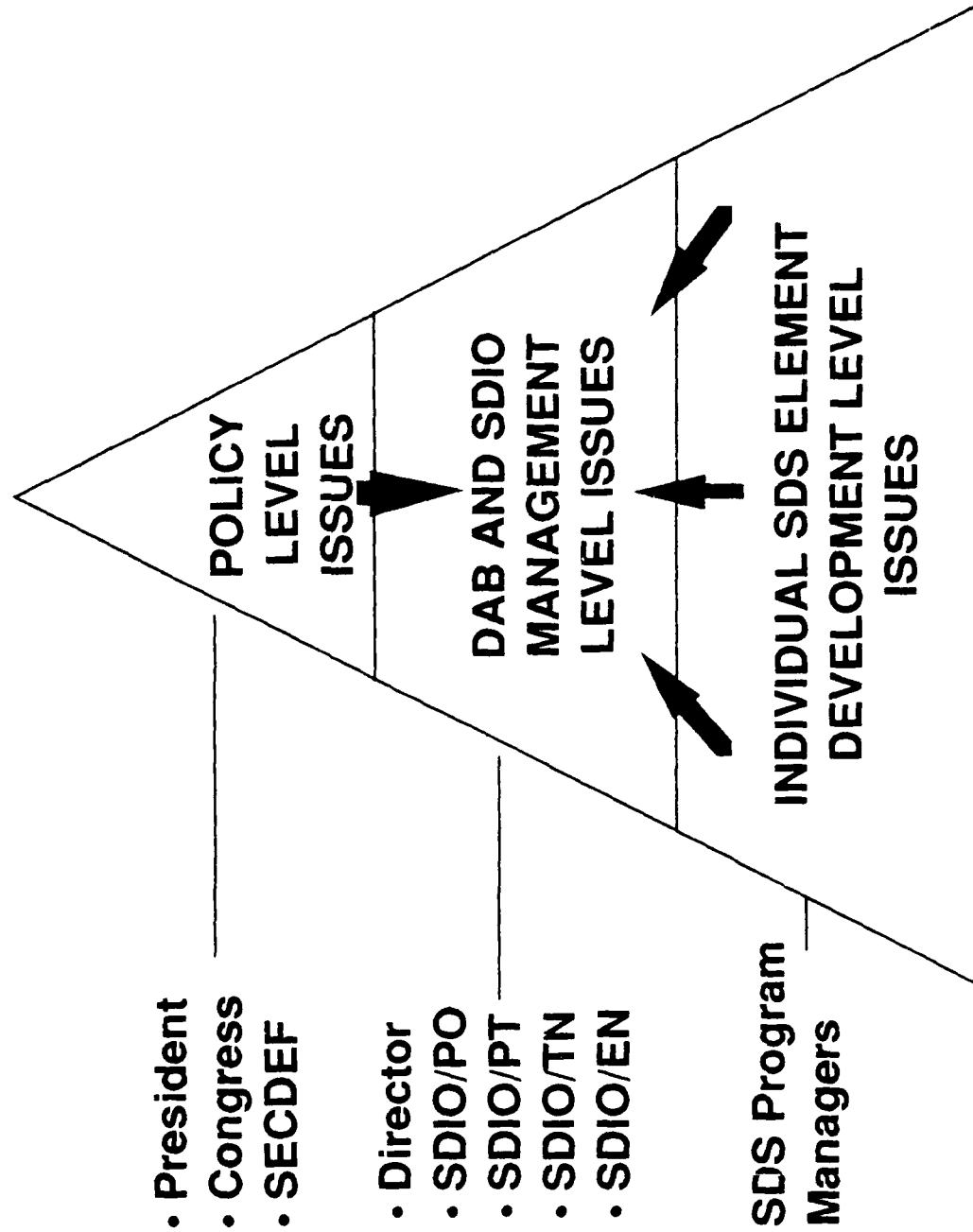
Figure 2 integrates the top down and bottom up issues, the DAB framework, the technical maturity levels of the assorted technologies, and the time reference. The technical maturity levels, influenced by the top down directives, define the required progress necessary for each individual program. Management decisions can then be made based on the relative maturity levels. For example, accelerating or decelerating a program (via budget actions) by comparing its current maturity level with the desired level.

Expanding the technology maturity definitions is crucial to the process. There are several efforts underway to develop decision

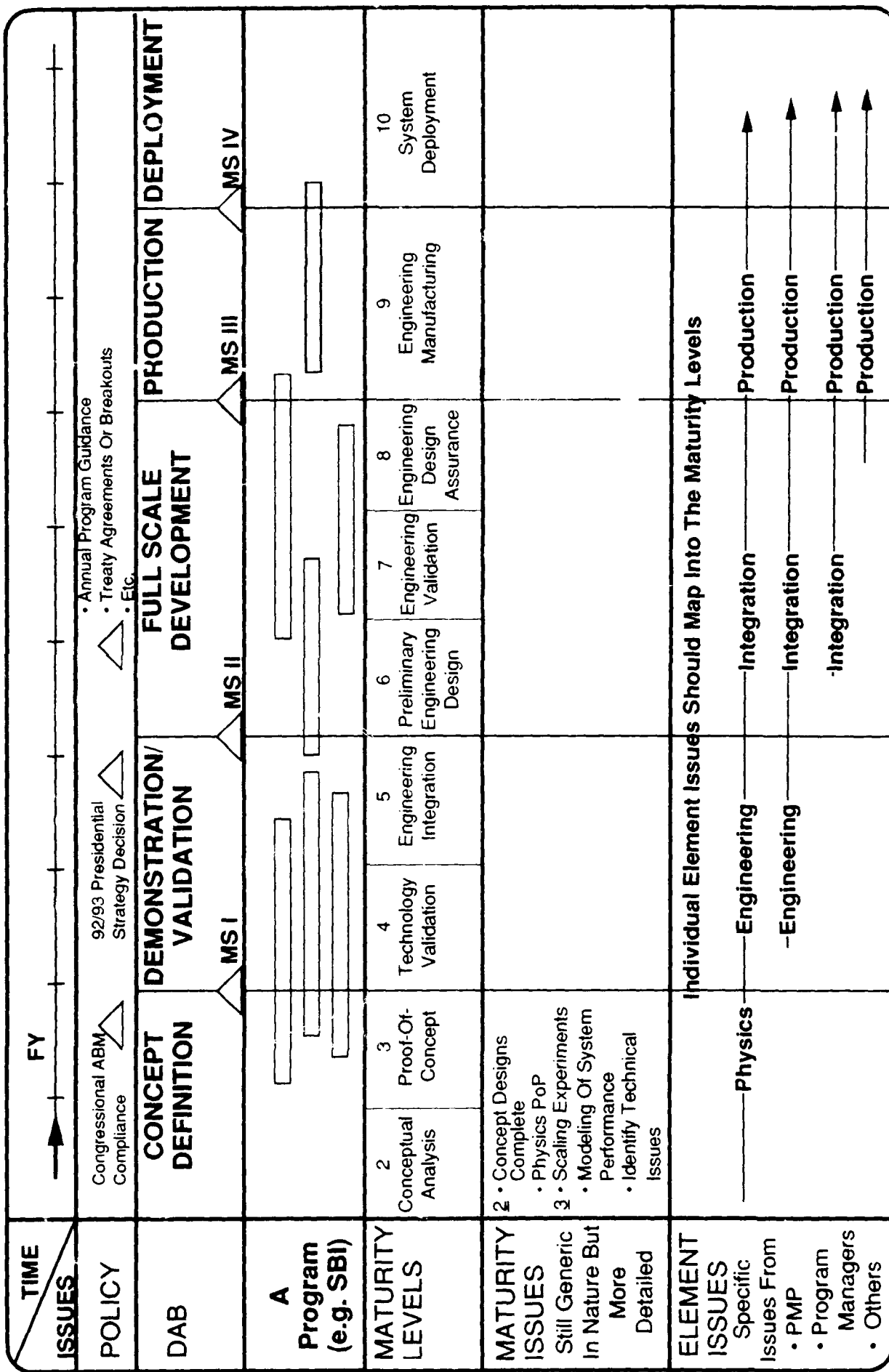
# Table 1: Mapping Technology Maturity Levels Into the DAB Process

| DEFENSE ACQUISITION BOARD PHASE         | TECHNOLOGY LEVEL                   | CURRENT DEFINITIONS                                                                                                     |
|-----------------------------------------|------------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| Mission Area Analysis (Pre Milestone 0) | 1 - Scientific Research            | 1 - Basic principles observed, hypothesis developed, and analysis performed                                             |
| MS 0: Concept Exploration/Definition    | 2 - Conceptual Analysis            | 2 - Conceptual design formulated, tradeoff studies and analysis performed                                               |
|                                         | 3 - Proof-of-Concept               | 3 - Conceptual design demonstrated analytically or experimentally                                                       |
|                                         |                                    |                                                                                                                         |
| MS I: Concept Demonstration/Validation  | 4 - Technology Validation          | 4 - Critical technology subsystems validated in relevant test environment                                               |
|                                         | 5 - Engineering Integration        | 5 - Integrated breadboard component/subsystem/system validated in relevant ground or space environment                  |
|                                         |                                    |                                                                                                                         |
| MS II: Full Scale Development           | 6 - Preliminary Engineering Design | 6 - Fabricate engineering model and quality, and/or integrate latest system to level performance requirements           |
|                                         | 7 - Engineering Validation         | 7 - Design, fabricate, and test prototype                                                                               |
|                                         | 8 - Engineering Design Assurance   | 8 - Demonstrate component/subsystem/system design assurance, involving adequacy of the engineering characteristics each |
|                                         |                                    |                                                                                                                         |
| MS III: Production                      | 9 - Engineering Manufacturing      | 9 - Demonstrate manufacturing techniques scaleable to peak production and affordability goals are successfully met      |
| Deployment                              | 10 - System Deployment             | 10 - Performance of the first article acceptance testing and deploy for operational utilization                         |

**Figure 1: The SDIO Program Is Pulled By Top  
Down And Bottom Up Issues**



# Figure 2: Integrating Policy, DAB, And Technology Development Issues



criteria for various aspects of the program. Some address DAB Milestone II criteria, others NSD 14 and the 1992/1993 Presidential decision. All these efforts can be valuable but they represent only single points in time. Key development decisions are based not only on current status but on the relative merits of proceeding to the next decision point or milestone eventually leading to the ultimate goal. All of these point-in-time decision criteria efforts should be integrated into the DAB development framework and checked from time to time for continued consistency and realistic progression toward the overall goals. Finally, the maturity level definitions must be usable by all program managers and with minimal variation in interpretation.

The use of simulation is one example of the need to expand on the definitions of technical maturity levels. More than perhaps any other past development program, SDS will depend on simulation and analysis, vice actual developmental and operational testing, to confirm performance. What needs to be proven by simulation and the respective levels of acceptability must be a part of technical maturity assessment. Figure 3 provides an example of how definitions could be expanded to account for such areas of increased emphasis as system level simulation.

### 2.3 Map Existing Program Development Issues Into Maturity Levels

The Program Master Plan contains a list of key issues for each SDIO element. These issues should define what must be done in order to meet an element's system goals. They should be the focus of the development thrust. Each SDS element should have a set of system Figures Of Merit (FOMs) or Measures of Effectiveness (MOE). These FOMs define the actual performance of the element and are used by the system architects to define the SDS capabilities. Technical issues should be expressed in terms of these FOMs and mapped into the maturity levels. Figure 4 illustrates a format for technical performance culminating in the actual mission requirement (the FOM). This approach aids in requirements traceability. As a system advances through the maturity levels, progress toward the system FOM is apparent. This approach of using actual parameters avoids schemes that attach levels of confidence or other subjective numbering systems to issues.

Once the individual issues are quantified, the technical maturity of the element as a whole can then be expressed in terms of these issues. Of course, the maturity levels for the various elements or technologies may be quite different for a given point in time. A



## Figure 3-Expanded Definitions

| <u>LEVEL</u> | <u>TASK</u>               | <u>EXPANDED DEFINITIONS (EXAMPLES)</u>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|--------------|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7            | ENGINEERING<br>VALIDATION | <p>-ENGINEERING DESIGN COMPLETE AND CHARACTERIZED IN HIGH-FIDELITY SIMULATION FOR INTEGRATION AT THE NTB.</p> <p>-CONDUCT DETAILED ENGINEERING DESIGN ANALYSES TO VERIFY PERFORMANCE INCLUDING SYSTEM LEVEL SIMULATIONS AT NTB ADDRESSING:</p> <ul style="list-style-type: none"> <li>--DEPLOYMENT AND SYSTEM INITIALIZATION</li> <li>--PEACETIME OPERATIONS</li> <li>--TRANSITION TO FULL-SCALE ENGAGEMENT</li> <li>--MAXIMUM THREAT ENGAGEMENT</li> <li>--OFF-NOMINAL CONDITIONS</li> </ul> <p>-CONDUCT ASSOCIATED DESIGN ANALYSES VIA NTB SIMULATIONS ADDRESSING:</p> <ul style="list-style-type: none"> <li>--SUPPORTABILITY</li> <li>--RELIABILITY, AVAILABILITY, MAINTAINABILITY</li> <li>--LIFE CYCLE COST</li> <li>--COMMAND CENTER/SYSTEM OPERATION AND INTEGRATION INTERFACES</li> </ul> <p>-CONDUCT SENSITIVITY ANALYSES ON CRITICAL PERFORMANCE CHARACTERISTICS FOR RISK ASSESSMENT</p> <p>-DESIGN, FABRICATE, AND TEST PROTOTYPE COMPONENTS OR SYSTEMS IN A RELEVANT TEST ENVIRONMENT WHICH MAY CONSIST OF HARDWARE-IN-THE-LOOP TESTING WITH NTB SYSTEM LEVEL SIMULATION TOOLS</p> |

**Figure 4: Program Development Issues Are Expressed In Terms Of System Goals And Mapped Into The Maturity Levels**

| ISSUE                                           | Maturity Levels     |     |     |     |     |     |     |     |     |     |     |
|-------------------------------------------------|---------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
|                                                 | Existing Capability | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  |
| <u>NPB</u><br>Beam Divergence (μr)              | 30                  | 30  | 30  | 15  | 15  | 8   | 8   | 8   | 8   | 8   | 8   |
| Power (Kg/Kw)                                   | 100                 | 100 | 100 | 50  | 35  | 20  | 20  | 20  | 20  | 20  | 20  |
| — Mission Requirement Level —→                  |                     |     |     |     |     |     |     |     |     |     |     |
| <u>SBI</u><br>Radial Velocity (km/s)            | 4                   | 2   | 3   | 4   | 4   | 5   | 8   | 9   | 9   | 9   | 9   |
| KKV<br>Wgt. (lbs.)                              | 300                 | 500 | 500 | 300 | 300 | 200 | 200 | 200 | 200 | 200 | 200 |
| <u>ALS</u><br>Noise Level 2 miles From Pad (dB) | 200                 | 200 | 200 | 100 | 100 | 60  | 60  | 60  | 60  | 60  | 60  |

basic rule would be that the element is no more mature than the level of its least mature issue. This will allow an element program manager to realign resources to balance his program in support of system level milestones or required maturity levels. At a higher level, it will allow the SDIO director to shift resources allocated to the elements and other parts of the program as necessary to achieve the desired maturity level of the system. To minimize the diversity of maturity levels among elements for the 1992/1993 Presidential decision, some programs may need to be accelerated while others are decelerated. Fig. 5, for example, shows why accelerating Brilliant Pebbles and decelerating SBI may be necessary so that both are at a comparable state of maturity in that time frame. The maturity definitions provide guidance on how the programs should be structured to meet this goal and provide a baseline to assess progress and compliance.

#### **2.4 Use The Program Control Office To Ensure Consistency**

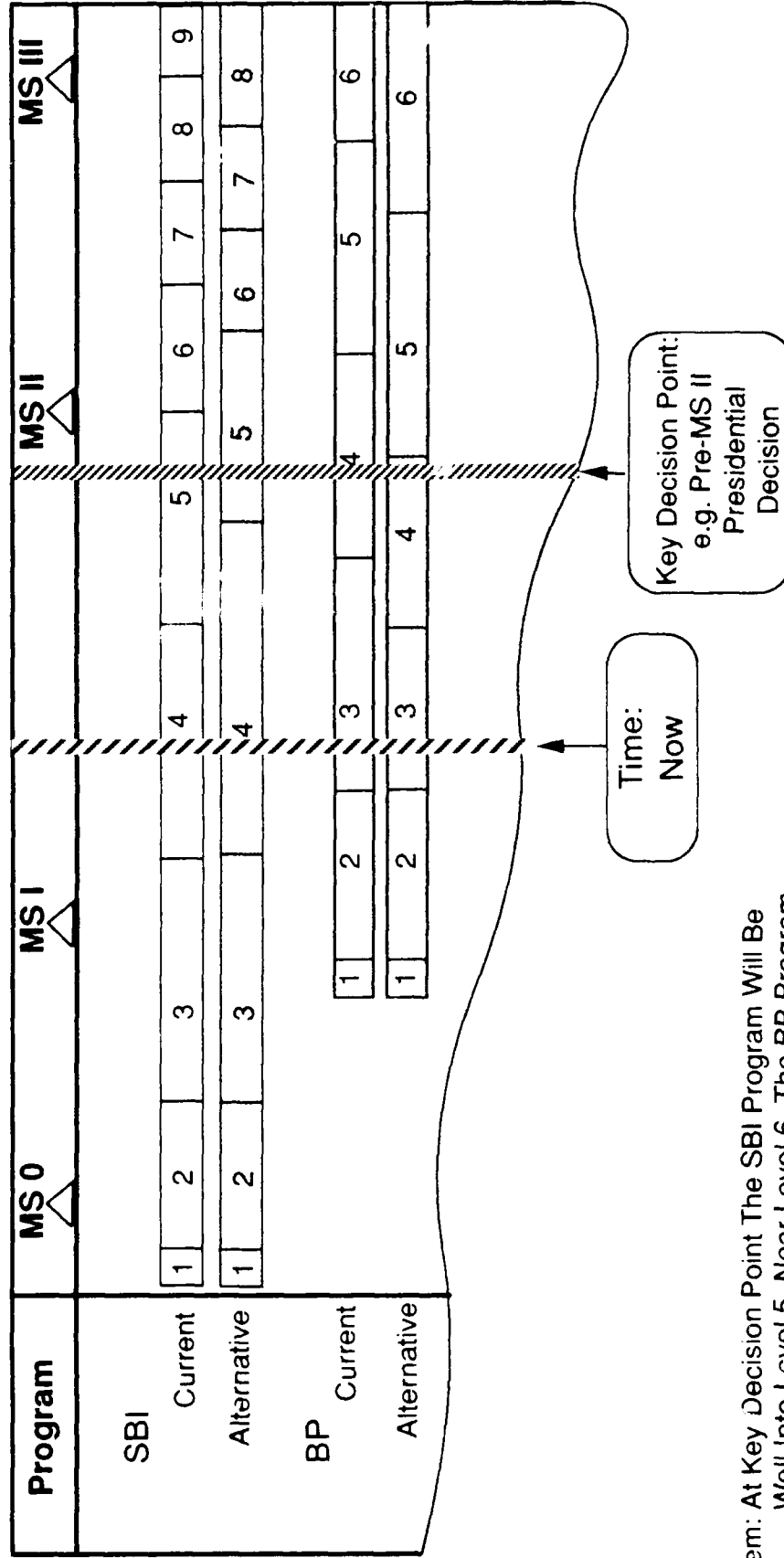
The recent reorganization of SDIO included plans for placing Planning and Control personnel in each of the Deputates. These personnel could be tasked with assisting the element program managers in using the maturity level definitions to depict their programs. The Planning and Control office should utilize their assessment capabilities to assess individual program progress and emphasize efforts to advance the technical maturity of the key issues. This creates a direct tie to budget and schedule. Figure 6 illustrates a step-by-step process for using technical maturity.

#### **2.5 Connectivity (Critical Path Analysis) and Risk Assessment**

By breaking the key issues into technical maturity levels, the element program manager can structure development in a sequential and evolving manner. This should yield a connectivity model that can be integrated directly into the overall SDS connectivity model. The relative maturity of one program to others as a function of time can be displayed. Decisions can be made concerning the allocation of resources to address shortfalls.

Risk assessment aids the decision making process because it can be performed in the context of evaluating progress through the maturity levels. The maturity levels would identify which issues were being addressed and exactly what kind of technological progress was required (e.g. moving from level 3 to 4 in the next FY). The PMA and connectivity data would describe the schedule and resources allocated. Risk assessment would examine the expected

# Figure 5: Balancing The Program Elements Using Technology Maturity

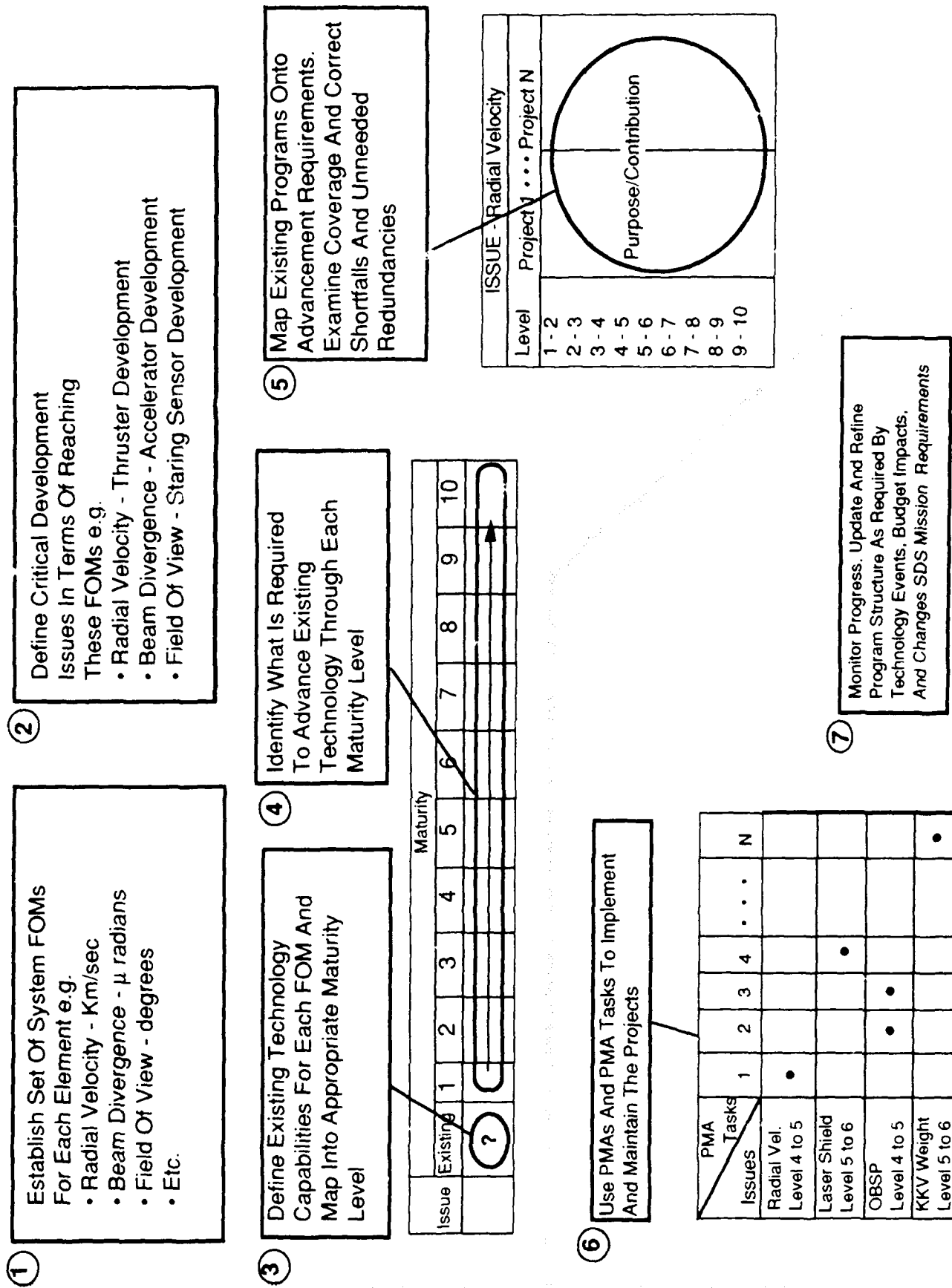


**Problem:** At Key Decision Point The SBI Program Will Be Well Into Level 5, Near Level 6. The BP Program Will Only Be Mid-Way Through Level 4. This Makes A Downselect Between The Two Concepts Difficult Due To The Disparity Of Data

**Solution:** Decelerate The SBI Program And Accelerate The BP Program. Use PMA Tasks To Reallocate Funds To Highest Potential Payoffs

**Result:** Minimized Disparity Between Key Programs. Overall, A More Balanced , Responsive Program

# Figure - 6: Steps In Using Technical Maturity



Planning And Structuring

Implementing

technical progress given the allocated resources and time and evaluate the probability of actually making that progress. (The exact risk assessment methodologies will be discussed in another paper. )

### 3. Summary

The effective use of the technical maturity methodology requires an overall system development structure or framework which the DAB process fulfills. Existing efforts to define decision criteria for program management guidance are valuable but do not go far enough. They must be used as input to the technical maturity level assessment methodology. Additional issues, such as the degree of simulation required, must be addressed in expanded definitions of the technical maturity levels. The process should be applied uniformly throughout SDIO which should be possible in light of the planned allocation of Planning and Control office personnel to the deputates. These efforts mesh well with risk analysis and critical path development work now ongoing which altogether create an integrated program model that will provide decision makers with the data and confidence they need to direct this very complex program.

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