# The Science and Technology Business Case with Systems Engineering

Tom Archer, Carol Ventresca, Bryan DeHoff, SynGenics
Bob Rapson, Jim Malas, Bob Enghauser, Bill Kesling, AFRL/RX
Gerry Hasen, Universal Technology Corporation
AFRL/RX Systems Engineering Team

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# Abstract

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This paper describes the use of Streamlined Systems Engineering techniques to build three classes of business case for S&T. The three classes answer three distinct questions:

- Is an S&T effort of value?
- What is the best S&T approach to a particular problem?
- How should a series of S&T candidates be prioritized?

AFRL's Materials and Manufacturing Directorate has developed a Streamlined Systems Engineering process that is flexible and adaptable to a wide range of problems, including building an S&T business case. The S&T Business Case is an objective analysis to support a decision about a commitment of resources. The Streamlined Systems Engineering approach to the S&T Business Case is structured, repeatable and creates and objective, defensible and traceable result that :

- Documents all of the factors essential to making an investment decision
- Includes a value proposition, an explicit declaration of estimated costs and a rationale that describes why the value is believed to be greater than the cost.

The term *Business Case* immediately suggests traditional financial measures that can be awkward or entirely inappropriate in S&T. Return on investment (ROI), internal rate of return (IRR), net present value (NPV) and payback are common examples. The *value proposition* approach is an effective way to deal with the economic imperatives.

The S&T Business Case is inherently discomforting and difficult, but the structured Streamlined Systems Engineering approach is a step-by-step process that is effective and powerful for focusing and defending S&T.



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# Outline

- Business case: working definition
- Three classes of business case
- Desirements (requirements)
- Alternatives
- Evaluation of alternatives (math)
- Case example

- Discussion

# Business Case
# A Working Definition

A *Case* is the totality of relevant facts.

The S&T Business Case is identical to any “Business Case” in purpose, which is to build an objective analysis to support a decision about a commitment of resources. The only real difference, nuance may be a better word, is the inherent immaturity of the science or technology, which means that relevant factors are more likely to be educated guesses than known details.

# Business Case
# A Working Definition

- Documents all of the factors essential to making an investment decision, including the supporting backup.

- Includes a value proposition: an explicit declaration of estimated costs and a rationale that describes why the value is believed to be greater than the cost.

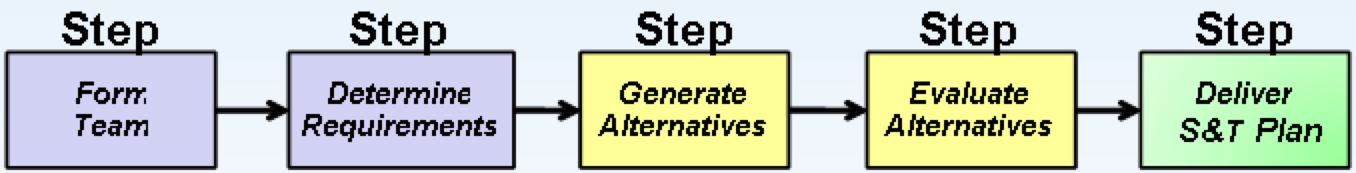
# S&T Business Case Difficulties

- It requires that we anticipate and analytically define an unknown and unknowable future.
- Supporting data has to be *created* from multiple *ad hoc* sources and it has to be consistent.
- Critical external elements have to be identified and evaluated such as enabling technologies and the systemic environment.
- Each business case is different; skilled judgment is required to identify the relevant issues.
- The Business Case developer's primary job and job skills are technically focused; case development may require additional training or support.

# Three Classes

- The "*Budget*" business case: A single investment candidate is evaluated for its ability to meet a set of objectives or *desirements*.
- The "*Tactical*" business case: Multiple alternatives with similar functional characteristics are compared for their ability to meet a set of objectives and the "best" are identified.
- The "*Strategic*" business case: Multiple alternatives, functionally dissimilar investment candidates are prioritized based upon their anticipated ability to achieve organizational objectives. best" are identified.

# Streamlined Systems Engineering



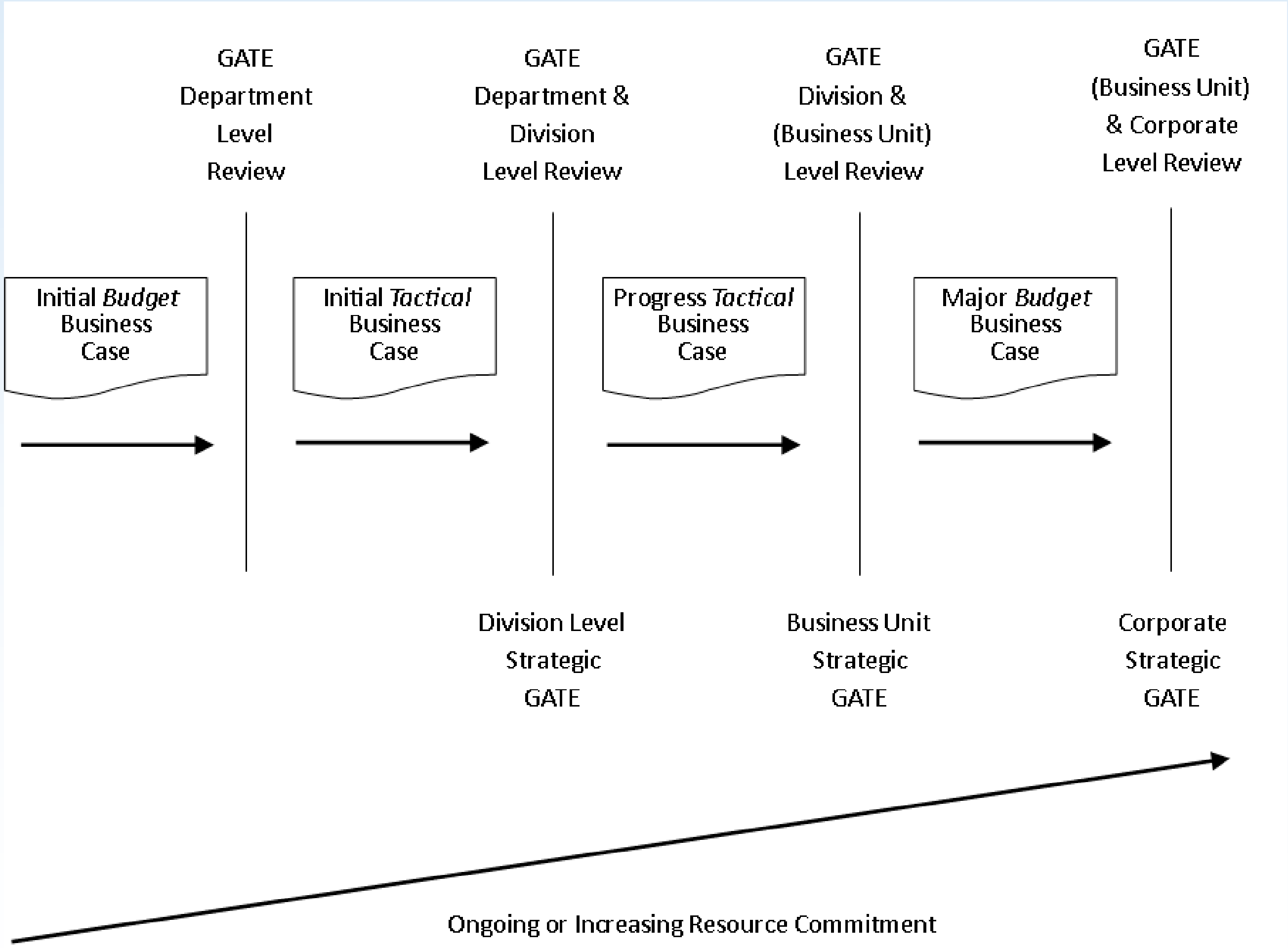
# S&T Business Case
# Based Upon SE Principles

- Measurable, validated objectives (*desirements*) in a systems context
- Alternatives that consider the system context for the application of the technology
- A supportable assessment of the expected performance of the investment candidate against those objectives and an estimate of the consequences of failure. (evaluation of alternatives)

# Comparison

| Process Steps | "Typical" Business Case | Systems Engineering Principles Applied |
|---|---|---|
| Team | Investment candidate "owners" only | "Owners" and interested parties including prospective end users (customers) |
| *Desirements* (Requirements) | Description of the investment candidate with key features. May include qualitative objectives such as "improved" or "enhanced." | Measurable objectives validated with the rationale for the objectives. |
| Alternatives | Only mentioned if the investment candidate is a replacement | Alternatives ( technical competitors) are explicitly identified when appropriate<br><br>Systems view: how does an alternative or investment candidate fit in the end user system, what enabling technologies have to be in place and are why are those enablers expected to be in place |
| Evaluation | Self-evident or non-existent with respect to objectives, but usually includes some kind of cost analysis | Structured analysis of the investment candidate's expected performance to the objectives (including costs), may include modeling and simulation.<br><br>Includes an estimate of the consequences of either not making the investment, or failing to meet objectives |
| Plan | Recommendation to proceed. | Recommendation to proceed or not, with an execution path and supporting rationale |

# Investment Decision "Gates"

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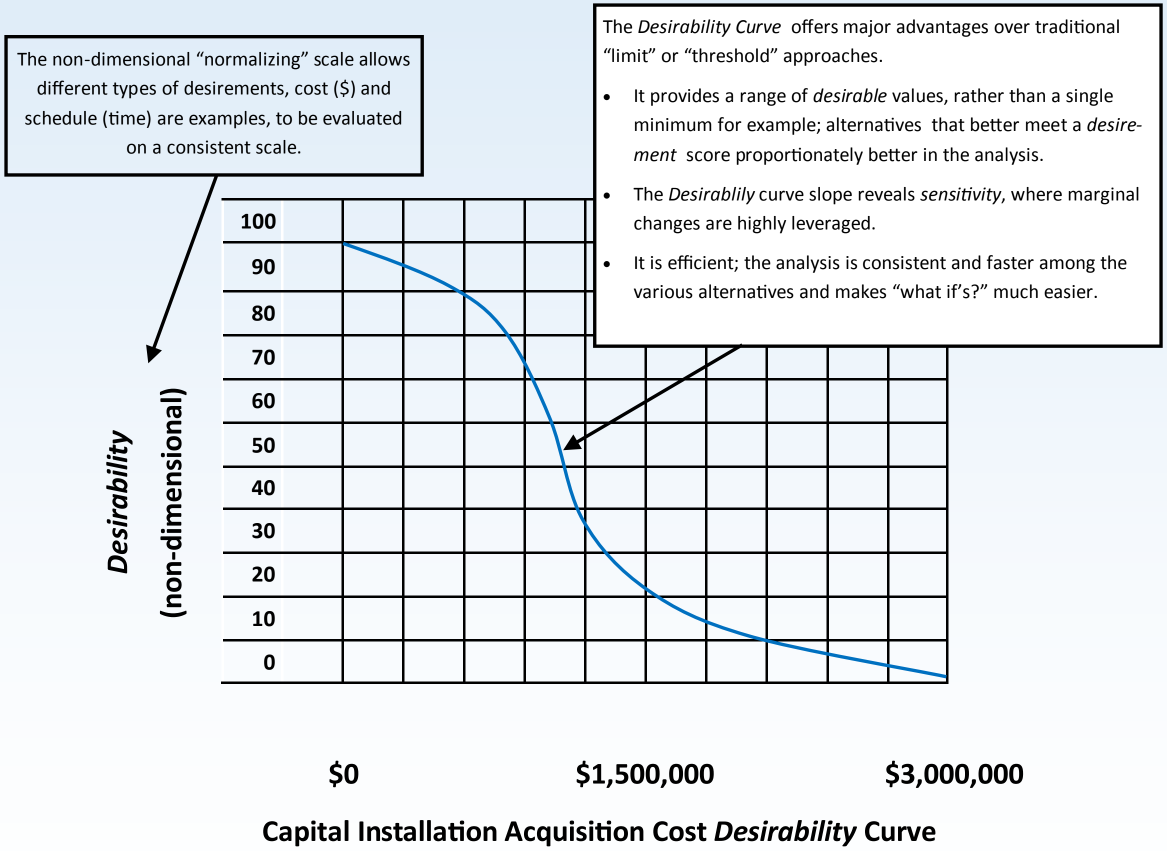
# S&T Business Case Element *Desirements*

- *Desirements*, objectives or *requirements* in systems engineering terms. *Desirements* define *success*.
- Desirements are characterized by:
  - label and brief description
  - unit of measure, or, for qualitative *desirements,* a scale
  - weighting factor relative to other *desirements*
  - a validated objective target with upper and/or lower limits
  - a *desirability* curve

# Desirability Curve



# S&T Business Case Element *Alternatives*

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- *Alternatives* within S&T are the technologies that are expected to meet the *desirements*.
  - For the Budget business case there is only one alternative.
  - For the Tactical business case, a technology alternative should be defined within a systems context or clearly understood that it is not.
  - A *systems view* does not imply that an S&T effort has to solve all the systems issues. It does mean that, within the business case, the state and expected evolution of the system environment be explicitly recognized and validated.
- An *alternative* is often represented by a Quad chart

# S&T Business Case Element
# Documentation of an *Alternative*

**Operational Capability:**

1) Current configurations require 4 m/sec (9 mph) wind speed to generate power. (Note that's not *average* wind speed.) Average speed at Kabul, Afganistan and Baghdad, Iraq exceed the minimum. Four months of the year the average wind speed at Panama City, Florida (Tyndall proximity) does not.

2) Wind speed at 150' above ground level is typically 2X to 3X that at the surface. So effective wind turbines are elevated.

3) Cost of ownership – total cost of ownership is currently estimated to be equivalent to commercially available grid electricity in the United States at $0.06 to $0.10 per kwh. That does not include the cost of erecting turbines at remote sites and connecting them to the grid.

4) Commercial catalog item from 1KW to 3MW. Larger sizes engineered to order.

5) The best use of wind power at a deployed base may be as supplemental where full required capacity is in place using say generators or fuel cells and wind energy, when available, is used to reduce fuel.

**Proposed Technical Approach:**

Need to be evaluated for suitability and impact issues at a deployed base:

1. Field erection issues may necessitate special tower construction.
2. Height may be an attractive target and a radar problem at a deployed air base.
3. Low frequency blade driven noise may be both irritating and a medical issue (not verified).

Alternative designs are in concept, could be evaluated.

1. Vertical axis alternatives with lower profiles, helix designs to operate at lower wind velocities and without the noise problems.

**Cost and Schedule:**

Acquisition cost: The most publicly available information on aggregate costs is based on T. Boone Pickens purchase of 667 1.5 Mw wind turbines from GE at $3 million each estimated installed cost. Additionally Pickens estimated another 25% to connect to the grid from the remote sites across 5 counties in the Texas panhandle.

Study costs to evaluate suitability to deployed bases and alternative designs:

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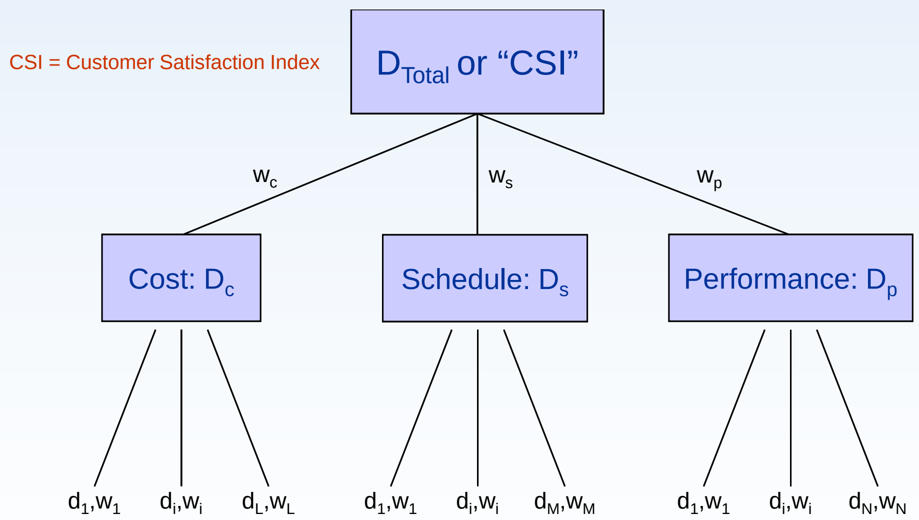
# S&T Business Case Element Evaluation of *Alternatives*

Weighted geometric mean with desirability for normalization

$$CSI = D_{Total} = [(D_c)^{w_c}(D_s)^{w_s}(D_p)^{w_p}]^{\frac{1}{w_c + w_s + w_p}}$$




*CSI* = Composite Satisfaction Index

# Why A Weighted Geometric Mean

## Weighted Geometric Mean

With a geometric mean, if an alternative fails to meet any *desirement*, it fails.

$d_2 = 0$ implies $D_c = 0$

$$D_c = [(d_1)^{w_1} (d_2)^{w_2} \cdots (d_L)^{w_L}]^{\frac{1}{\sum_{i=1}^{L} w_i}}$$

## Weighted Arithmetic Average

With an arithmetic average, failure to meet any *desirement*, can be hidden and offset by a high score meeting other *desirements*.

$d_2 = 0$ does not imply $D_c = 0$

$$D_c = \frac{w_1 d_1 + w_2 d_2 + \ldots + w_L d_L}{w_1 + w_2 + \ldots + w_L}$$

# Tactical Business Case

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An example based upon an evaluation of energy alternatives for a remote location

| Systems Engineering Scorecard - Con't: Composite_Scorecard | Desirement Type | | | | | | | | | | | | Affordability | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Remote Site Energy Alternatives | Cost | | Human Factors | | Logistics | | Operating Environment | | Performance | | Schedule | | | |
| Weight | 1 | | 1 | | 2 | | 1 | | 2 | | 1 | | D | Risk |
| Technology Alternative | d | $P_F$ | d | $P_F$ | d | $P_F$ | d | $P_F$ | d | $P_F$ | d | $P_F$ | | |
| Tri-Generation - Recovery | 0.800 | 0.1587 | 1.000 | 0.0000 | 0.962 | 0.0450 | 1.000 | 0.0228 | 0.791 | 0.5114 | 1.000 | 0.0000 | **0.918** | **0.6169** |
| MicroTurbine w/ Conventional Generator | 0.463 | 0.3085 | 1.000 | 0.0000 | 0.735 | 0.1965 | 1.000 | 0.0228 | 0.583 | 0.2921 | 1.000 | 0.0000 | **0.760** | **0.6244** |
| Fuel Cell - Solid Oxide with bulk storage and Integrator | 0.255 | 0.0668 | 1.000 | 0.0000 | 0.995 | 0.0450 | 1.000 | 0.0228 | 0.758 | 0.4182 | 0.271 | 0.0228 | **0.698** | **0.5161** |
| Biofuel Generation - Biodiesel Ponds | 0.000 | 1.0000 | 0.000 | 1.0000 | 0.000 | 0.5889 | 0.500 | 0.1587 | 0.000 | 1.0000 | 0.909 | 0.0000 | **0.000** | **1.0000** |
| Superconductor Generators | 0.000 | 0.5334 | 0.894 | 0.0002 | 0.000 | 0.5114 | 1.000 | 0.0228 | 0.000 | 1.0000 | 0.000 | 0.5007 | **0.000** | **1.0000** |
| Solar - Photovoltaics with Integrator and Bulk Storage | 0.000 | 1.0000 | 0.000 | 0.5000 | 0.000 | 1.0000 | 1.000 | 0.0228 | 0.000 | 1.0000 | 0.572 | 0.0000 | **0.000** | **1.0000** |
| Solar- Thermal Concentrator, Steam Generator | 0.000 | 0.5000 | 0.000 | 1.0000 | 0.000 | 1.0000 | 1.000 | 0.0000 | 0.000 | 1.0000 | 0.572 | 0.0000 | **0.000** | **1.0000** |
| Chemical Batteries - Bulk Storage General Technolo | 0.000 | 1.0000 | 0.000 | 0.5000 | 0.000 | 0.8778 | 1.000 | 0.0228 | 0.000 | 1.0000 | 0.862 | 0.0000 | **0.000** | **1.0000** |
| Wind Turbine with Integrator and Bulk Storage | 0.000 | 1.0000 | 0.560 | 0.0228 | 0.000 | 0.9891 | 1.000 | 0.0228 | 0.000 | 1.0000 | 0.572 | 0.0000 | **0.000** | **1.0000** |
| MicroTurbine with Super Conducting Generator | 0.000 | 0.6133 | 0.894 | 0.0002 | 0.995 | 0.0450 | 1.000 | 0.0228 | 0.804 | 0.5114 | 0.000 | 0.5007 | **0.000** | **0.9560** |
| Nuclear with Integrator | 0.348 | 0.1587 | 0.000 | 0.5114 | 0.000 | 0.8948 | 1.000 | 0.0228 | 0.943 | 1.0000 | 0.716 | 0.0000 | **0.000** | **1.0000** |
| Space Based Solar Power - Beamed | 0.000 | 0.5114 | 0.560 | 0.0228 | 1.000 | 0.0450 | 1.000 | 0.0228 | 0.932 | 0.0450 | 0.311 | 0.0228 | **0.000** | **0.5846** |
| Conventional Generator with on-site Bio-diesel | 0.000 | 1.0000 | 0.000 | 1.0000 | 0.000 | 1.0000 | 1.000 | 0.0228 | 0.000 | 1.0000 | 0.862 | 0.0000 | **0.000** | **1.0000** |
| Customer: Solar PV Flexible Over Shelter | 0.492 | 0.1587 | 1.000 | 0.0000 | 0.735 | 0.1965 | 1.000 | 0.0228 | 0.000 | 1.0000 | 0.862 | 0.0000 | **0.000** | **1.0000** |
| Biodiesel from Algae Reactors with Conventional Ge | 0.000 | 1.0000 | 0.000 | 0.5000 | 0.000 | 1.0000 | 1.000 | 0.0228 | 0.000 | 1.0000 | 0.000 | 0.5007 | **0.000** | **1.0000** |

# Tactical Business Case

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Each *desirement* type is a composite of several individual *desirements*. Cost, for example, includes development, acquisition and operating costs.

…ation of energy alternatives for a remote location

| Remote Site Energy Alternatives | Desirement Type | | | | | | | | | | | | Affordability | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cost | | Human Factors | | Logistics | | Operating Environment | | Performance | | Schedule | | | |
| Weight | 1 | | 1 | | 2 | | 1 | | 2 | | 1 | | D | Risk |
| Technology Alternative | d | $P_F$ | d | $P_F$ | d | $P_F$ | d | $P_F$ | d | $P_F$ | d | $P_F$ | | |
| Tri-Generation - Recovery | 0.800 | 0.1587 | 1.000 | 0.0000 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| MicroTurbine w/ Conventional Generator | 0.463 | 0.3085 | 1.000 | 0.0000 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Fuel Cell - Solid Oxide with bulk storage and Integrator | 0.255 | 0.0668 | 1.000 | 0.0000 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Biofuel Ge… | [illegible] | [illegible] | [illegible] | 1.0000 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Supercond… | [illegible] | [illegible] | [illegible] | 0.0002 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Solar - Pho… | [illegible] | [illegible] | [illegible] | 0.5000 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Solar- The… | [illegible] | [illegible] | [illegible] | 1.0000 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Chemical … | [illegible] | [illegible] | [illegible] | 0.5000 | 0.000 | 0.8778 | 1.000 | 0.0228 | 0.000 | 1.0000 | 0.862 | 0.0000 | 0.000 | 1.0000 |
| Wind Turb… | [illegible] | [illegible] | [illegible] | 0.0228 | 0.000 | 0.9891 | 1.000 | 0.0228 | 0.000 | 1.0000 | 0.572 | 0.0000 | 0.000 | 1.0000 |
| MicroTurbine with Super Conducting Generator | 0.000 | 0.6133 | 0.894 | 0.0002 | 0.995 | 0.0450 | 1.000 | 0.0228 | 0.804 | 0.5114 | 0.000 | 0.5007 | 0.000 | 0.9560 |
| Nuclear with Integrator | 0.348 | 0.1587 | 0.000 | 0.5114 | 0.000 | 0.8948 | 1.000 | 0.0228 | 0.943 | 1.0000 | 0.716 | 0.0000 | 0.000 | 1.0000 |
| Space Based Solar Power - Beamed | 0.000 | 0.5114 | 0.560 | 0.0228 | 1.000 | 0.0450 | 1.000 | 0.0228 | 0.932 | 0.0450 | 0.311 | 0.0228 | 0.000 | 0.5846 |
| Conventional Generator with on-site Bio-diesel | 0.000 | 1.0000 | 0.000 | 1.0000 | 0.000 | 1.0000 | 1.000 | 0.0228 | 0.000 | 1.0000 | 0.862 | 0.0000 | 0.000 | 1.0000 |
| Customer: Solar PV Flexible Over Shelter | 0.492 | 0.1587 | 1.000 | 0.0000 | 0.735 | 0.1965 | 1.000 | 0.0228 | 0.000 | 1.0000 | 0.862 | 0.0000 | 0.000 | 1.0000 |
| Biodiesel from Algae Reactors with Conventional Ge | 0.000 | 1.0000 | 0.000 | 0.5000 | 0.000 | 1.0000 | 1.000 | 0.0228 | 0.000 | 1.0000 | 0.000 | 0.5007 | 0.000 | 1.0000 |

Every alternative is evaluated with respect to every *desirement*, receiving both a *desirement* score and a composite score.

Failure of an alternative to meet any *desirement* means both its *desirement* score and composite score will be zero.

# Strategic Business Case

# Streamlined Systems Engineering
## Same Basic Process – Different Details

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SYSTEMS ENGINEERING AFRL/RX

| Step 1 | Step 2 | Step 3 | Step 4 | Step 5 |
|---|---|---|---|---|
| ***Form Team*** | ***Determine Requirements*** | ***Generate Alternatives*** | ***Evaluate Alternatives*** | ***Deliver S&T Plan*** |
| Executive Team | Strategic Requirements (could be stage gate requirements) | Investment Alternatives | Score Alternatives (evaluated during a regular review process) | Roadmaps & Budget |

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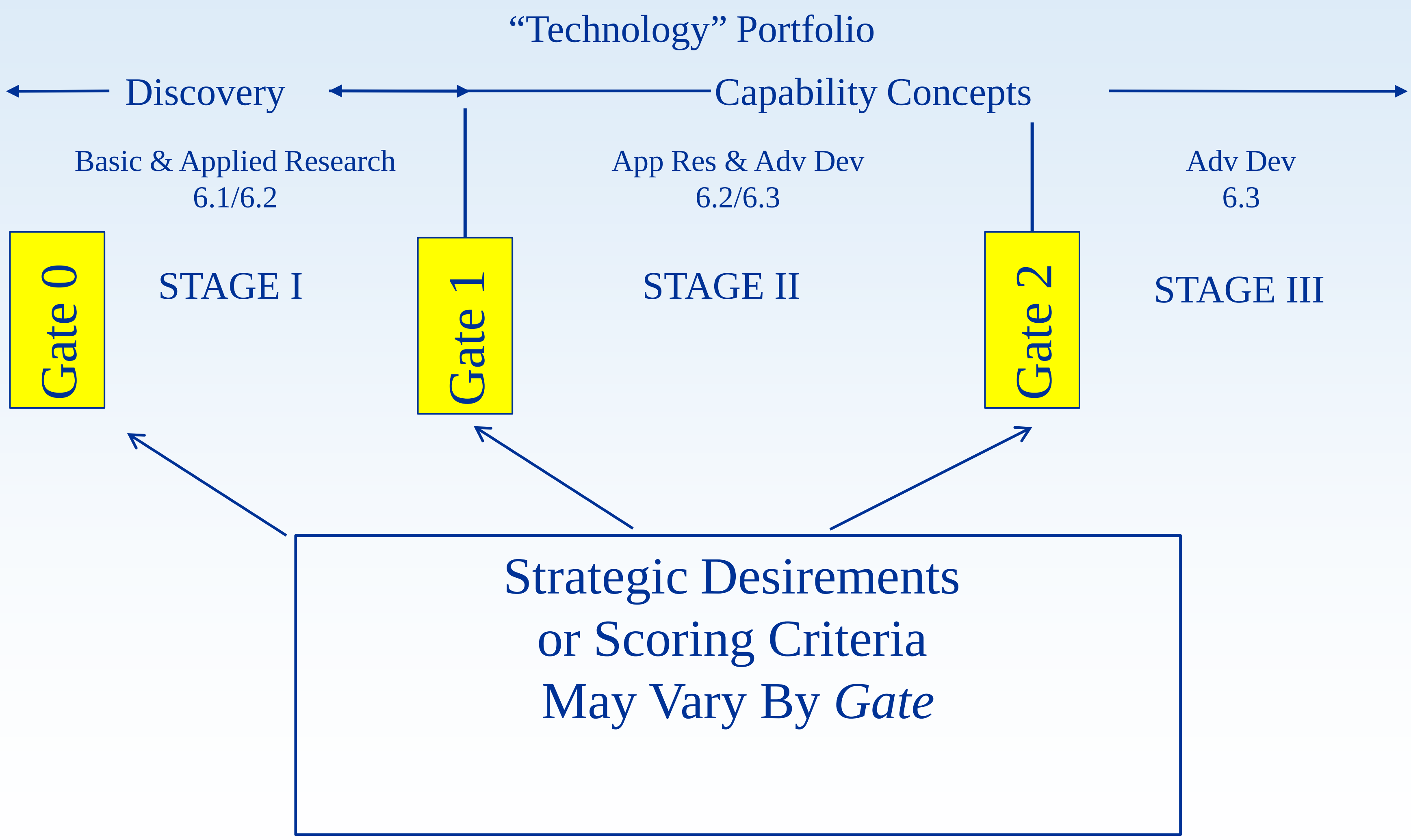
# Desirements Reflect Level of Management

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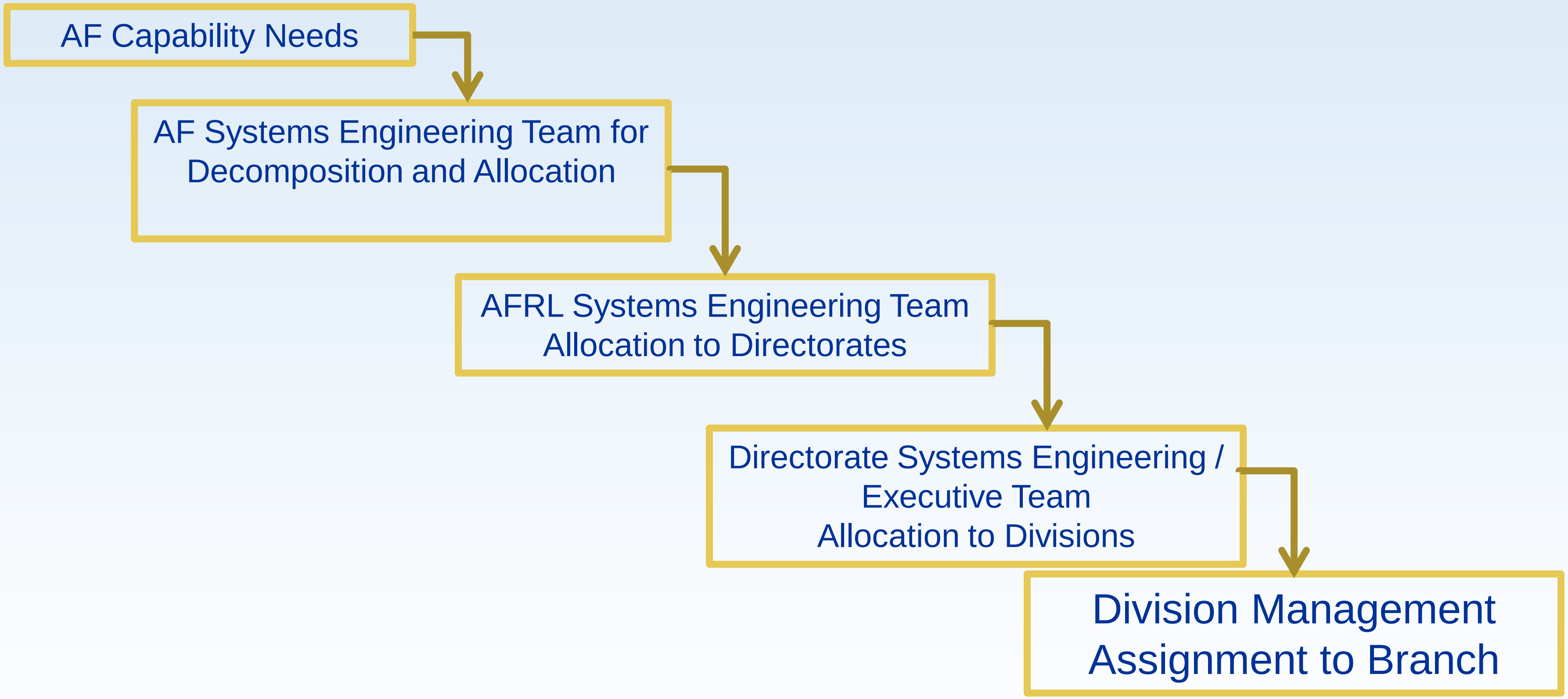
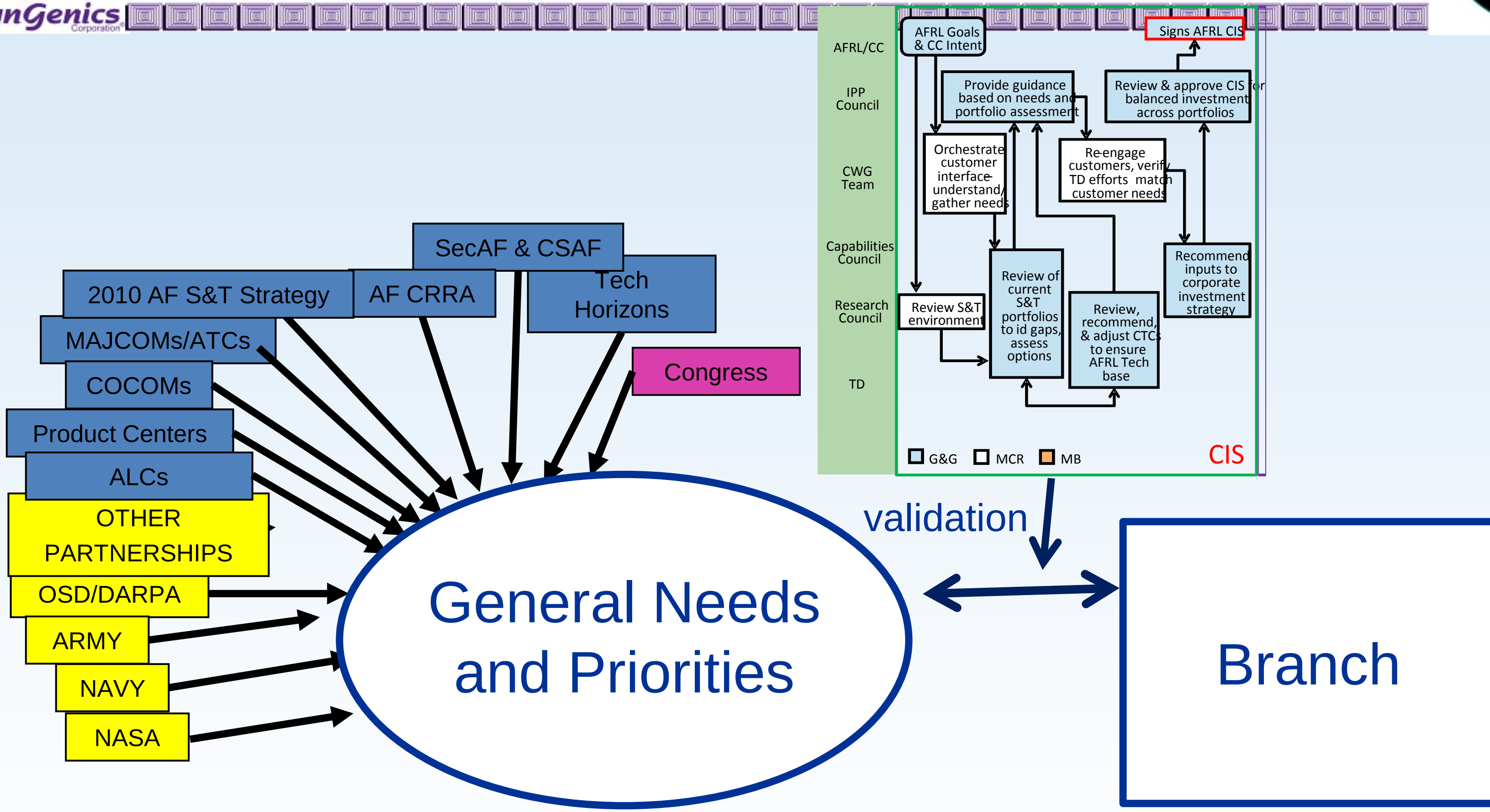
# Strategic Desirements
# Ideal "Top Down" / Flow Down World



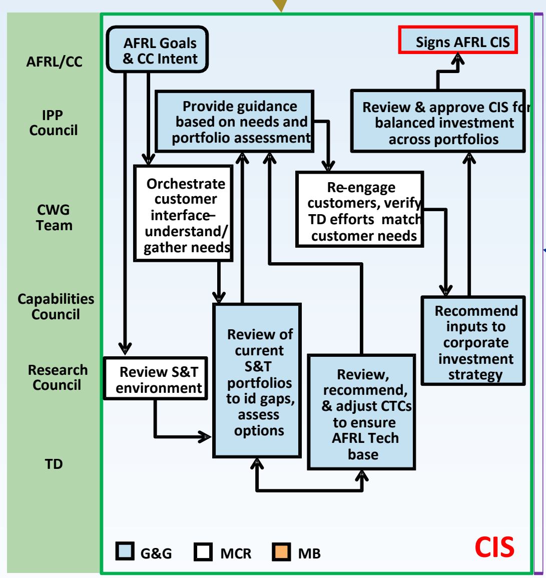
# Product Requirements Actual Practice




SME's at the Branch level respond to their understanding of explicit external needs and priorities (pull) and propose new capabilities (discovery and push) in response to their understanding of the user environment.

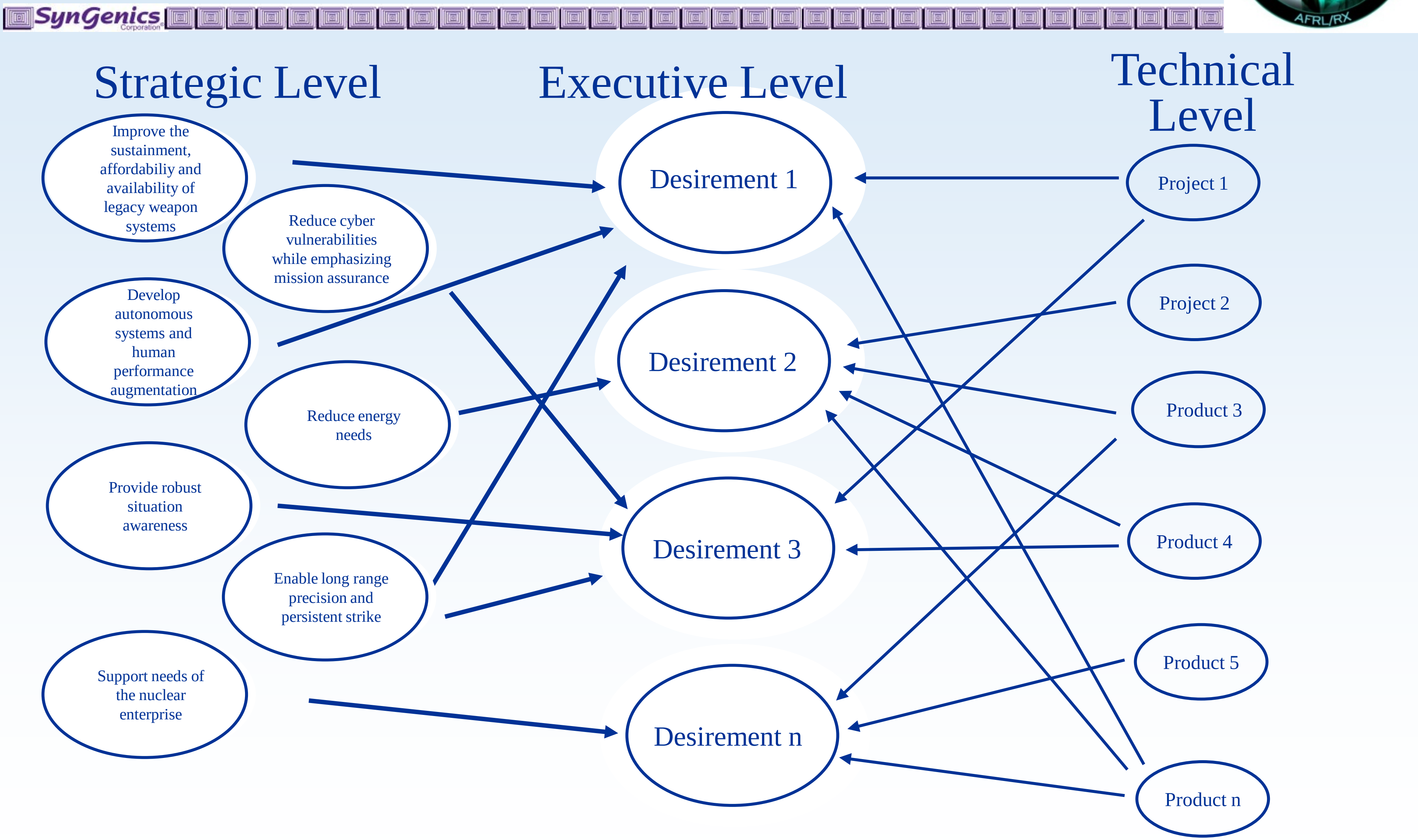
# Requirements - Current Practice

AF Development Needs




Branch

# Strategic Linkage to Products

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# Formulate *Desirements* For Strategic Levels (examples)

- Meets one or more strategic objectives
- Clearly defined, actively engaged customer or sponsor (pull)
- Customer desirements are explicit and understood
- Success is defined, such as an agreed upon ATD and timing
- Meets *discovery* criteria (push)
- Is a unique AF skill, urgent requirement or unique requirement.
- Represents the best approach among alternatives or one of the best approaches
- Is a critical technology or critical enabling technology
- Requires another enabling technology that is, or is not funded
- Financial
- Risk
- Directed effort

# The Eight Questions

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## Applied Research (6.2) Question and Answer Matrix

| Key Question | Question Breakdown | What the Program Manager should know about his or her program | Color Assessment Basis<br>B=Excellent G=Satisfactory Y=Marginal R=Unsatisfactory |
|---|---|---|---|
| **1. Who is your customer?** | Who are the external customers, users, sponsors, & other stakeholders? | Money source; report recipient; SPO; MAJCOM | **B:** Best practice candidate - exceeds Green. Internal and external customers identified to include targeted SPO(s) and MAJCOM users.<br>**G:** Key customers identified and actively involved, providing funding and management commitment; 6.3 customer buy-in secured.<br>**Y:** Know who might be interested, but have no buy-in, formal or informal; 6.3 manager within directorate provides verbal advocacy.<br>**R:** No attempt to find customers interested in using technology. |
| | What does each bring to the | Funding; interest | |
| | How is each one involved in the program? | Receive report; Interested in using technology | |
| | Who are the internal customers, users, sponsors, & other stakeholders? | 6.3 Program Manager who is interested; Technical Directorate or Division | |
| | How is each one involved in the program? | Interested in using technology | |
| **2. What are customer's requirements?** | How has each customer, user, sponsor, & other stakeholder defined what they expect you to deliver? | MOU; CDRL; Other contractual requirements; DTIC Final Report | **B:** Best practice candidate - exceeds Green. Uses validated tools to help track and manage customer requirements derived from a formal agreement, e.g., Technology Development Strategy (TDS).<br>**G:** Key customer requirements clearly and quantitatively defined in a written document (MOU,TDS, CDRL).<br>**Y:** Some customers provided general description of desired deliverable(s).<br>**R:** Customer requirements are poorly defined. |

AFRL Systems Engineering Guidebook, 5 July 2012, Companion Document to AFRLI 61-104, Table 4.2

# Strategic Desirements (draft example with scoring)

| SE Projects Assessment 6.2 Strategic Desirements<br>Proposed (Draft)<br>Weightings TBD | | | |
|---|---|---|---|
| | | | Proposed Scoring Basis<br>1 to 10, 10 is best |
| **Desirements** | **Desirement Breakdown** | **What the Program Manager Should Know** | **Scoring Criteria** |
| **1. ACTIVE/ENGAGED END USER**<br><br>Every project or program actively engages a prospective end user of the S&T | Who are the external customers, users, sponsors, & other stakeholders? | Money source; report recipient; SPO; MAJCOM | **9-10:** Internal and external customers identified to include targeted SPO(s) and MAJCOM users who are funding or will fund a phase of the program.<br><br>**5-8:** Key customer(s) identified and actively involved, by participating in requirements development, reviews or providing funding and management commitment; 6.3 customer buy-in secured. An official POC exists.<br><br>**3-4:** A customer or prospect has expressed interest by committing to participate, but has not participated in an active way.<br><br>**2:** No customer or prospect is directly involved, but potential end users have been identified<br><br>**1:** No customer or prospect is directly involved; end users have not been identified. |
| | What does each bring to the program? | Funding; interest | |
| | Who are the internal customers, users, sponsors, & other stakeholders? | 6.3 Program Manager who is interested; Technical Directorate or Division | |
| | How is each one involved in the program? | Interested in using technology | |

# Strategic Desirements - 2 (draft example with scoring)

| Desirements | Desirement Breakdown | What the Program Manager Should Know | Scoring Criteria |
|---|---|---|---|
| **2. KNOWN/AGREED REQUIREMNENTS**<br><br>The customer's requirements, including cost, performance and other relevant parameters that define success are known and agreed upon. | How has each customer, user, sponsor, & other stakeholder defined what they expect you to deliver? | | **9-10:** Uses validated TMATT/IPPD tools to help track and manage fulfillment of customer requirements derived from a formal Technology Development Strategy (TDS).<br><br>**6- 8:** Key customer requirements clearly and quantitatively defined in a written requirements document (MOU, TDS, CDRL).<br><br>**2 – 5:** Some specific customer provided general description of desired deliverable(s), but the customer has committed to work to (jointly) develop requirements.<br><br>**0-1:** No customer, no requirements or the requirements are not specific. |
| **3. DEFINED/AGREED DEMONSTRATION PLAN**<br><br>An agreed upon technology or project success demonstration plan has been defined. | What are the exit criteria you have to meet to transition technology to the next phase? | Show how technology could meet a need | **9-10:** Full, formal test or demonstration plan complete.<br><br>**5-8:** Formal test ore demonstration plan is outlined, including brief list of resources required, activities and data to be collected.<br><br>**3-5:** General expectations for a demonstration are known, but there's no demonstration plan.<br><br>**0-2:** Notional thoughts about what a demonstration plan would be |

# Strategic Desirements - 3 (draft example with scoring)

| Desirements | Desirement Breakdown | What the Program Manager Should Know | Scoring Criteria |
|---|---|---|---|
| **8. PROJECT PLAN CREATED**<br><br>A formal, feasible project plan, including tasks, schedule, budget and staffing has been prepared. | Describe the program structure in technical, contractual, financial, and managerial terms (including the roles and responsibilities of individuals and teams/IPTs). | Name of principal investigator and/or contractor, PI / contractor's experience and credentials, who else is on project team, where will work be done, what type of contract (BAA, PRDA, etc.) | **9-10:** Research team organized as an Integrated Product Team with clear responsibilities and a written charter, schedule and budget.<br><br>**7-8:** Formal risk management plan incorporated into program structure. Key program members have necessary skills, knowledge, time and ability to apply to effort; Adequate allocation of resources (e.g., facilities and funding structure). Both functional and physical Work Breakdown Structure (WBS) developed to guide program effort.<br><br>**4-6:** Risk mitigation marginally incorporated into program management structure. Program structure not well defined; individual responsibilities poorly understood. Some key program members lack necessary experience and time to apply to effort. Some needed resources (e.g., facilities and funding structure) may be lacking. WBS in place, but not sufficiently developed.<br><br>**0-3:** Risk not adequately addressed in program management structure. Key program members do not have necessary skills, knowledge, time and ability to apply to effort. Inadequate allocation of resources. No physical or functional WBS. |
| | What is the work breakdown structure (or equivalent) of your program? | Functional work breakdown structure for the work you're trying to do | |
| | Describe your program's risk management process. | Formal risk management program; how do you intend to deal with risk drivers identified above? | |

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# Strategic Desirements - 4 (draft example with scoring)

SynGenics Corporation

| Desirements | Desirement Breakdown | What the Program Manager Should Know | Scoring Criteria |
|---|---|---|---|
| **9. TRANSITION PLAN**<br><br>A business-based technology transition plan has been approved by the prospective end user. | What formal or informal transition agreement(s) do you have and with whom? | MOU; Informal agreement with 6.3 PM; Using command / SPO expressed interest | **9-10:** Formal transition agreement with 6.3 program manager; using MAJCOM / SPO formally identifies transition window(s) of opportunity.<br><br>**5-8:** Formal transition plan available in draft, not yet fully coordinated. Potential additional customers included in the RDT&E effort.<br><br>**3-4:** Developed transition plan for some of the key customers. Plan to include potential customers in the RDT&E effort, but they're not there yet.<br><br>**0-2:** Nonexistent transition plan. No plan to include additional customers in the RDT&E effort. |
| | What potential customers do you still need to develop transition plans for and what is your plan to develop these? | Who else might be interested? How do you plan on telling them about your technology? | |
| **10. CLEAR AIR FORCE STRATEGIC VALUE**<br><br>This project has clear strategic value to the Air Force. | Does this represent an AFRL core competency commitment or is it so urgent it's an AFRL [command] priority, or it's a unique operational need. | New or enhanced strategic capability; New or enhanced tactical capability; urgent and compelling challenge, need or application is significantly different from commercial, industry or academia unwilling or unable; AF is SME, AF is SOA, AF commitment | **9-10:** Meets more than one strategic criterion.<br><br>**5-8:** Meets at least one of the three strategic criteria.<br><br>**3-4:** The strategic value is tentative, may depend on additional understanding.<br><br>**0-2:** No strategic value. |

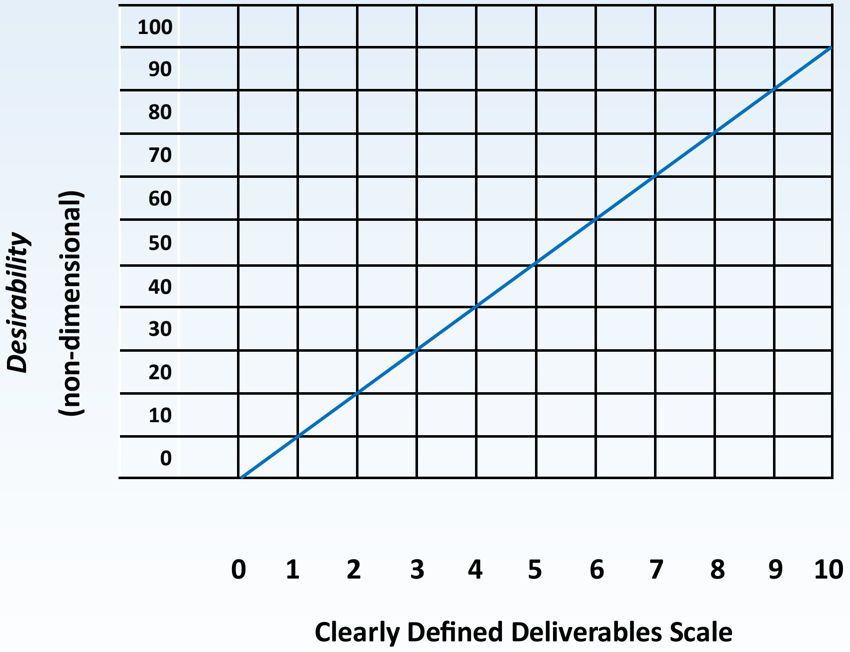
# Strategic Desirements - 5 (draft example with scoring)

SynGenics Corporation

SYSTEMS ENGINEERING AFRL/RX

| Desirements | Desirement Breakdown | What the Program Manager Should Know | Scoring Criteria |
|---|---|---|---|
| **11. TECHNOLOGY INTEGRATION**<br><br>Integration of the technology has been evaluated and is understood is not an obstacle to adopting the technology. | Does this technology necessarily fit within a specific system, either real or conceptual?<br><br>Are there other enabling technologies that are essential for this technology's function that are not part of this project/program?<br><br>Are there other technologies that are either not developed, or are also in development that are essential to the success of this technology. | Should have at least a notional architecture or functional breakdown if this is part of a system.<br><br>*(A material, say a composite, could stand alone or it could be a project because it's an essential part of a system.)* | **9-10:** It's part of a clearly defined system; interfaces are understood and any other technologies essential to this technology already exist.<br><br>**6-8:** The technology stands alone or its systemic role is well understood and there are no expected gaps in implementation.<br><br>**3-5:** The technology is part of a system but there are gaps in understanding or other essential parts of the system.<br><br>**0-2**: Don't know or know, but the systems impacts haven't been formally addressed. |

# Clearly Defined Deliverables Desirability Curve - Linear



# Clearly Defined Deliverables Draft Scale

| Clearly Defined Deliverables Desirement Scoring Criteria | | | |
|---|---|---|---|
| 10 | Test or demonstration plan approved. | 5 | Test or demonstration plan outlined, significant deficiencies or uncertainties in understanding customer requirements or the ability to meet them. |
| 9 | High probability draft test or demonstration plan will be approved. | 4 | A test or demonstration plan exists, but there are no customers involved. |
| 8 | Demonstration plan tied to customer requirements has been developed; under review by customer. | 3 | Partial test or demonstration plan exists, but there are no customers involved, low confidence customers are interested or will participate. |
| 7 | Demonstration plan draft exists, based upon customer input. | 2 | A partial test or demonstration plan exists, but no customers are involved and there is a low probability objectives will be achieved. |
| 6 | Test or demonstration based upon customer requirements outlined, including resources required, activities and data to be collected. | 1 | Notional or qualitative test or demonstration plan, no customer involvement. |
| | | 0 | No test or demonstration plan, or no confidence it can be executed or meets customer expectations. |

# The Mathematics of the Previous Spreadsheet

$$CSI = [(D_c)^{w_c}(D_s)^{w_s}(D_p)^{w_p}]^{\frac{1}{w_c + w_s + w_p}}$$

CSI = composite score index
D = desirability score for a product to a desirement
w = weight for the desirement

# Summary

SynGenics Corporation

- The Business Case with Systems Engineering
  - Measurable, validated objectives (*desirements*) in a systems context
  - Alternatives that consider the system context for the application of the technology
  - A supportable assessment of the expected performance of the investment candidate against those objectives and an estimate of the consequences of failure. (evaluation of alternatives)
- The Streamlined Systems Engineering process is flexible and can be used for all three classes of business case:
  - It offers comparability at the level competing for resources
  - It offers a consistent framework for discussion and negotiation
  - It is a tool for building the business case; it does not "make" decisions; it empowers the decision maker
- The process is efficient
  - Interested parties define the expectations
  - It offers consistency, traceability, and defensibility

# Contact Information

Thomas Archer
SynGenics Corporation
5190 Olentangy River Road
Delaware OH 43015
Email: archer@syngenics.com
Direct phone: 614-442-7858

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# Island Winery

Reliable
Energy
Problems

- 30 year old winery
- Electricity no longer subsidized by government, price increasing
- Electricity is unreliable, out at least an hour a week
- No electricity for 6 to 8 contiguous days at least once a year

# Island Winery

- If the winery loses the ability to promptly process and chill their juice during the harvest, they will lose a portion of their crop.
- If electricity is out, winery loses substantial daily income from visitors who tour, eat and buy wine by the bottle and case
- The pavilion is available for events, a typical event sells at least 50 cases of wine
- The winery is no longer able to buy insurance for losses resulting from weather or electrical outages.

# Island Winery – Initial Thoughts

- The problem is the consequences of unreliable energy, primarily costs but also the intangibles of not being able to serve customers.

- In the worst case, they could lose half a crop, they're out a minimum of $3 million in marginal revenue, maybe more, but they decided not to worry about that unless it proves to be important. The somewhat arbitrary conclusion was that the cost of securing reliable energy would be attractive if it were under $500,000, but could be considered at up to $3 million.

- Different parts of the operations can survive without electricity for different periods of time but with a couple of exceptions, there was no agreement on what those were. Some thought the pavilion's customers would accept an hour's inconvenience, others thought ten minutes might be too long, especially if it resulted in major delays in the restaurant's kitchen. The conclusion was that five minutes or less of interruption was a problem with negligible consequences. A half hour was the upper limit for the pavilion and grape processing. The juice tank chillers could tolerate four hours. The control system was already on battery backup. The conclusion was that an interruption of up to a half hour was tolerable for the pavilion and processing and all other operations could tolerate 4 hours maximum.

# Island Winery – Initial Thoughts

- Any solution should be "environmentally sensitive" although that was not defined. The specific thought was that "noisy diesel generators belching black smoke close to the pavilion would not be good."

- The project established an arbitrary budget of $20,000 out-of-pocket expenses, exclusive of internal staff, and a target completion time of six weeks. Expected expenses included equipment to measure and monitor current loads and travel to visit sites with similar problems and implemented solutions. The owners offered that "it's worth $20,000 to know if we have options."

# Island Winery – Initial "Desirements"

- Electrical interruption limits
- A solution cost range
- An intangible "environmentally sensitive" expectation
- A time limit
- Project cost.

The overall project objective, the "driver" for these desirements is simply to get a perspective on whether there are probable, feasible solutions (alternatives) to the reliability problem.

# Island Winery – Electricity Rate Change

The operations manager also contacted the utility, got no encouragement with the reliability issue, but did learn that their rate structure was about to change dramatically. The old structure was based heavily on actual usage, with a power factor surcharge and load ratchet clause. The new structure was more complex:

- An availability charge estimated at $7,500 per month
- A “load factor” charge, estimated to be $3,500, based upon the highest usage rate for 15 minutes anytime in the previous 18 months
- A power factor surcharge if the power factor dropped below 90%
- An actual kilowatt-hour usage charge.

The utility was able to provide the most recent four years of usage data, in 15-minute increments.

# Electrical Energy Summary

| Summary of Electrical Energy Usage, Cost and Estimates | |
|---|---|
| Last year's total electrical energy usage | 610,000 KWH |
| Last year's total electrical energy bills | $96,554 |
| Last year's peak demand | 490 KVA |
| Average off-season monthly usage (7 months) | 24,500 KWH |
| Average off-season peak load | 70 KW |
| Projected energy usage = no change | 610,000 KWH |
| Project year's total energy bill under the new rate structure | $150,800 |

# Energy Usage

| Description | Running Load (watts) | Starting Load (watts) | Total Load (watts) |
|---|---|---|---|
| **Pavilion HVAC** | 86,000 | 110,000 | 110,000 |
| **Pavilion Lighting, Office and Miscellaneous** | 20,000 | 20,000 | 20,000 |
| **Pavilion Kitchen Including Water Heater** | 28,000 | 28,000 | 28,000 |
| **Total Pavilion** | 134,000 | 158,000 | 158,000 |
| **Processing Barn Crushers** | 96,000 | 116,000 | 116,000 |
| **Processing Barn Chillers** | 120,000 | 170,000 | 170,000 |
| **Processing Barn Lighting and Miscellaneous** | 40,000 | 40,000 | 40,000 |
| **Total Processing Barn** | 256,000 | 326,000 | 326,000 |
| **Maintenance Barn Lighting and Miscellaneous** | 30,000 | 30,000 | 30,000 |
| **Maintenance Barn Lift** | 5,000 | 7,500 | 7,500 |
| **Maintenance Barn Air Compressor** | 20,000 | 25,000 | 25,000 |
| **Total Maintenance Barn** | 55,000 | 62,500 | 62,500 |

# Intermediate Technical Findings

- Based upon the total load, with rounding, the operations manager had talked to vendors and a 600 KW diesel generator, with control and switch gear would run around $100,000 with another $50,000 for freight, engineering, permits, and a fuel system.

- That was below their initial $500,000 threshold. The Maintenance Barn was almost a mile from the Processing Barn and Pavilion, which were in close proximity so visitors could tour both. There was a discussion about whether the Maintenance Barn needed to be included and the conclusion was to keep the total load aggregated, but when all the data was in they would decide whether to simply provide a separate solution for the Maintenance Barn, or move it closer to the other facilities.
- So the target was 600KW of on-site backup power.

# Island Winery Desirements

| Des # | Desirement Name | Priority | Meas Unit | Objective | Type | Desirement Description |
|---|---|---|---|---|---|---|
| **C1** | Acquisition or First Cost | Med | $ | 250,000 | Cost | Total acquisition cost |
| **C2** | Annual Fully Amortized Cost | Med | $ | $150,000 | Cost | Operating costs including fuel, and maintenance |
| **H1** | Skill Level Required for Use | High | Scale: 3 to 7 | 3 | HF | Skill level required for the user to make use of the system; based on company job descriptions |
| **H2** | Manhours Required to Operate Per 24 Hours | High | Manhours | 1 | HF | Amount of manning required to operate the system, measured as manhours per 24 hours of operation. |
| **L1** | Service Life | Med | Years | 10 | Other | Estimate of useful service life with regular maintenance, without overhaul, years |
| **L2** | Scalability, Modularity, Flexibility | Med | Scale: 1 to 3, 3 being easily scalable | 3 | Other | Flexibility and Modularity are expected, measure is KW increment of additional capacity. 25KW is 1 |

# Island Winery Desirements - 2

| Des # | Desirement Name | Priority | Meas Unit | Objective | Type | Desirement Description |
|---|---|---|---|---|---|---|
| **S1** | Initial Operational Capability | High | Years from now, this year = 0 | 0 | Other | Fiscal year in which a system could be operational employing the technologies in the alternative. |
| **E1** | "Green-ness" | Low | Scale: 1 to 3 | 1 | Other | Estimated perception, scale 1 to 3. 3 is fully renewable, 2 is better than existing, something renewable, 1 is existing grid or generator |
| **P01** | Nominal Power | High | KW | 450 | Perf | Continuous power which the system is capable of providing in KW. |
| **P02** | Surge Capacity | High | % of Nominal | 35 | Perf | Spike surge capacity, for 3 seconds |
| **P03** | Reliability | High | MTBF | 10,000 | Perf | Mean time to failure (MTBF), assuming appropriate service is performed, in hours. |

# Island Winery Alternatives

- *Conventional Diesel Generator*, Switchgear, Load Management, and Integration
- *Multiple Diesel Generators* (same total capacity as single generator), Switchgear, Load Management, and Integration
- *Single Stage MicroTurbine* w/ Conventional Generator, Switchgear, Load Management, and Integration
- *Dual Stage MicroTurbine*, Switchgear, Load Management, and Integration
- *Solar - Photovoltaics* with Integration and Battery Bulk Storage, Switchgear, Load Management, and Integration
- *Solar- Thermal Concentrator*, Steam Generator with Working Fluid Storage, Switchgear, Load Management, and Integration
- *Fuel Cell*- Solid Oxide with Integration, Switchgear, Load Management, and Integration
- *Wind Turbine* with Integration and Bulk Storage, Switchgear, Load Management, and Integration

| Island Winery | (C1) Acquisition or First Cost | (C2) Annual Fully Amortized Operating Cost | (E1) "Green-ness" | (H1) Skill Level Required for Use | (H2) Manhours Required to Operate Per 24 Hours | (L1) Service Life | (L2) Scalability, Modularity, Flexibility | (P01) Nominal Power | (P02) Surge Capacity-Spike | (P03) Reliability | (S1) Initial Operational Capability | **Composite Desirability** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Weight** | **1.0** | **1.0** | **1.0** | **1.0** | **1.0** | **3.0** | **3.0** | **5.0** | **1.0** | **3.0** | **2.0** | |
| **Multiple Diesel Generators** | 240000 | 220815 | 1 | 3 | 2 | 20 | 3 | 400 | 20 | 10000 | 0 | **0.973** |
| Desirability | 1.000 | 0.721 | 1.000 | 1.000 | 0.802 | 1.000 | 1.000 | 1.000 | 1.000 | 0.978 | 1.000 | |
| **Conventional Diesel Generator** | 75000 | 315448 | 1 | 3 | 2 | 20 | 3 | 400 | 20 | 10000 | 0 | **0.946** |
| Desirability | 1.000 | 0.396 | 1.000 | 1.000 | 0.802 | 1.000 | 1.000 | 1.000 | 1.000 | 0.978 | 1.000 | |
| **Dual Stage MicroTurbine** | 480000 | 159328 | 2 | 4 | 2 | 20 | 3 | 400 | 20 | 10000 | 1 | **0.812** |
| Desirability | 1.000 | 0.962 | 0.500 | 0.618 | 0.802 | 1.000 | 1.000 | 1.000 | 1.000 | 0.978 | 0.214 | |
| **Single Stage MicroTurbine w/ Conventional Generator** | 360000 | 252536 | 2 | 5 | 2 | 30 | 3 | 400 | 110 | 10000 | 1 | **0.771** |
| Desirability | 1.000 | 0.605 | 0.500 | 0.314 | 0.802 | 1.000 | 1.000 | 1.000 | 1.000 | 0.978 | 0.214 | |
| **Solar - Photovoltaics with Integration, Bulk Storage** | 1400000000 | 200610000 | 3 | 4 | 6 | 7 | 3 | 400 | 0 | 10000 | 12 | **0.000** |
| Desirability | 0.000 | 0.000 | 0.000 | 0.618 | 0.297 | 0.306 | 1.000 | 1.000 | 0.000 | 0.978 | 0.000 | |
| **Solar- Thermal Concen., Steam Generator** | 2200000000 | 110024400 | 3 | 5 | 24 | 30 | 1 | 400 | 20 | 10000 | 3 | **0.000** |
| Desirability | 0.000 | 0.000 | 0.000 | 0.314 | 0.000 | 1.000 | 0.153 | 1.000 | 1.000 | 0.978 | 0.000 | |
| **Fuel Cell - Solid Oxide with bulk storage and AI** | 2400000 | 311289 | 3 | 4 | 2 | 20 | 3 | 400 | 0 | 8000 | 1 | **0.000** |
| Desirability | 0.482 | 0.409 | 0.000 | 0.618 | 0.802 | 1.000 | 1.000 | 1.000 | 0.000 | 0.800 | 0.214 | |
| **Wind Turbine with Integration and Bulk Storage** | 1800000 | 102200 | 3 | 5 | 1 | 20 | 3 | 400 | 10 | 4000 | 2 | **0.000** |
| Desirability | 0.540 | 1.000 | 0.000 | 0.314 | 1.000 | 1.000 | 1.000 | 1.000 | 0.584 | 0.029 | 0.015 | |

| Island Winery | (C1) Acquisition or First Cost | (C2) Annual Fully Amortized Operating Cost | (E1) "Green-ness" | (H1) Skill Level Required for Use | (H2) Manhours Required to Operate Per 24 Hours | (L1) Service Life | (L2) Scalability, Modularity, Flexibility | (P01) Nominal Power | (P02) Surge Capacity-Spike | (P03) Reliability | (S1) Initial Operational Capability | **Composite Desirability** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Weight** | **1.0** | **1.0** | **1.0** | **1.0** | **1.0** | **3.0** | **3.0** | **5.0** | **1.0** | **3.0** | **2.0** | |
| **Multiple Diesel Generators** | 240000 | 220815 | 1 | 3 | 2 | 20 | 3 | 400 | 20 | 10000 | 0 | **0.973** |
| Desirability | 1.000 | 0.721 | 1.000 | 1.000 | 0.802 | 1.000 | 1.000 | 1.000 | 1.000 | 0.978 | 1.000 | |
| **Conventional Diesel Generator** | 75000 | 315448 | [illegible] | [illegible] | [illegible] | 20 | 3 | 400 | 20 | 10000 | 0 | **0.946** |
| Desirability | 1.000 | [illegible] | [illegible] | [illegible] | [illegible] | 1.00 | [illegible] | [illegible] | [illegible] | [illegible] | 1.000 | |
| **Dual Stage MicroTurbine** | 480000 | [illegible] | [illegible] | [illegible] | [illegible] | 20 | [illegible] | [illegible] | [illegible] | [illegible] | 1 | **0.812** |
| Desirability | 1.000 | [illegible] | [illegible] | [illegible] | [illegible] | 1.00 | [illegible] | [illegible] | [illegible] | [illegible] | 0.214 | |
| **Single Stage Micro Turbine w/ Conventional Generator** | 360000 | 252536 | 2 | 5 | 2 | 30 | 3 | 400 | [illegible] | [illegible] | [illegible] | **0.771** |
| Desirability | 1.000 | 0.605 | 0.500 | 0.314 | 0.802 | 1.000 | 1.000 | 1.000 | [illegible] | [illegible] | [illegible] | |
| **Solar - Photovoltaics with Integration, Bulk Storage** | 1400000000 | 200610000 | 3 | 4 | 6 | 7 | 3 | 400 | 0 | 10000 | 12 | **0.000** |
| Desirability | 0.000 | 0.000 | 0.000 | 0.618 | 0.297 | 0.306 | 1.000 | 1.000 | 0.000 | 0.978 | 0.000 | |
| **Solar- Thermal Concen., Steam Generator** | 2200000000 | 110024400 | 3 | 5 | 24 | 30 | 1 | 400 | 20 | 10000 | 3 | **0.000** |
| Desirability | 0.000 | 0.000 | 0.000 | 0.314 | 0.000 | 1.000 | 0.153 | 1.000 | 1.000 | 0.978 | 0.000 | |
| **Fuel Cell - Solid Oxide with bulk storage and AI** | 2400000 | 311289 | 3 | 4 | 2 | 20 | 3 | 400 | 0 | 8000 | 1 | **0.000** |
| Desirability | 0.482 | 0.409 | 0.000 | 0.618 | 0.802 | 1.000 | 1.000 | 1.000 | 0.000 | 0.800 | 0.214 | |
| **Wind Turbine with Integration and Bulk Storage** | 1800000 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 4000 | 2 | **0.000** |
| Desirability | 0.540 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 0.029 | 0.015 | |

This is the estimated value, in this case the estimated Acquisition Cost for Multiple Diesel Generators

This is the *desirability* for the Reliability desirement

This is the Composite Desirability

As an example, Solar Thermal fails to meet 4 desirements, so it has zero desirability. If an alternative fails to meet any desirement, it will have zero composite desirability. From the table it is easy to quickly see where an alternative fails.

| | Payback | Affordability | Timeliness | Customer Focused | Compliance - legal, social, environmental | Internal Capacity to Manage | Downside Limited | Composite Strategic Desirability Score |
|---|---|---|---|---|---|---|---|---|
| **WEIGHT** | **3** | **3** | **1** | **1** | **2** | **1** | **3** | |
| | | | | | | | | |
| **Projects** | | | | | | | | |
| | | | | | | | | |
| **Electric Load Management** | 10 | 10 | 10 | 5 | 10 | 10 | 10 | 952 |
| **CO2 Harvesting Tank** | 5 | 10 | 10 | 10 | 10 | 10 | 10 | 862 |
| **Automated Bottle Inspection** | 10 | 10 | 6 | 10 | 10 | 6 | 6 | 833 |
| **Electrical Power Project** | 7 | 10 | 10 | 10 | 6 | 10 | 6 | 772 |
| **New Harvester** | 10 | 5 | 10 | 3 | 6 | 10 | 10 | 735 |
| **Boat Dock and Bus** | 2 | 10 | 7 | 10 | 10 | 10 | 8 | 658 |
| **600 Acre Land Acquisition** | 4 | 10 | 10 | 5 | 10 | 10 | 4 | 643 |
| **Market Expansion West** | 4 | 10 | 10 | 10 | 5 | 4 | 6 | 625 |
| **200 acre expansion** | 10 | 4 | 10 | 8 | 6 | 4 | 4 | 579 |
| **Automated Casing Line** | 4 | 5 | 6 | 2 | 5 | 10 | 10 | 551 |
| **Champagne Warehouse** | 4 | 4 | 10 | 10 | 5 | 10 | 4 | 503 |
| **Market Expansion Europe** | 2 | 4 | 6 | 10 | 5 | 3 | 6 | 418 |
| | | | | | | | | |
| | | | | | | | | |

# Draft Raw Data Sheet

| | Active / Engaged End User | Known / Agreed Upon Requirements | Defined / Agreed Upon Demonstration Plan | Formal Analysis of Alternatives | Expected Value In Line With Costs | Represents the best approach among alternatives | Clear Air Force Strategic Value | Risks Managed | Formal Feasible Project Plan | Technology Transition Plan | Systems Issues Evaluated and Understood | Composite Score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WEIGHT** | **3** | **3** | **1** | **1** | **2** | **1** | **3** | **2** | **3** | **3** | **5** | |
| | | | | | | | | | | | | |
| **PRODUCTS** | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| **Product 1** | 5 | 2 | 5 | 4 | 3 | 2 | 2 | 6 | 8 | 3 | 2 | 321 |
| **Product 2** | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 4 | 5 | 8 | 6 | 297 |
| **Product 3** | 2 | 1 | 3 | 1 | 3 | 1 | 1 | 5 | 10 | 4 | 5 | 279 |
| **…** | | | | | | | | | | | | |
| **Product n** | | | | | | | | | | | | |

Distribution A: Approved for Public Release, Case Number 88ABW-2012-5949

# Summary

- The Business Case with Systems Engineering
  - Measurable, validated objectives (*desirements*) in a systems context
  - Alternatives that consider the system context for the application of the technology
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- The process is efficient
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  - It offers consistency, traceability, and defensibility

# ATD / HVP Example

See #15241 – *Using the Streamlined Systems Engineering Method for S&T to Identify Programs with High Potential To Meet Air force Needs, Dr. Gerry Hasen, UTC, Track 4 – Early Systems Engineering, 2:40 PM, Wednesday, October 24, 2012*