# Recapturing System Decomposition Techniques for Improved S&T Development of Future Warfighter Capabilities

## --- SE Tailored to Science and Technology ---


James Malas, AFRL Plans and Programs Directorate

Carol Ventresca and Tom Archer, SynGenics Corporation

Robert Rapson, AFRL Materials and Manufacturing Directorate



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# Purpose

**This paper explores the use of system decomposition techniques such as Work Breakdown Structure (WBS) as useful systems engineering tools for planning, executing, and transitioning Science and Technology (S&T) programs.**

# Overview

- **Science and Technology is different**
- **Working "System" Definition & Semantics**
- **Tailoring System Decomposition Techniques for S&T**
- **Incorporation in the S&T Systems Engineering Process**
- **Example: Off-Grid Electric Power Capability**

# S&T Is Different

- S&T does not lend itself to the more evolved processes and common tools of Systems Engineering that apply to mature technology.
- At the S&T stage there are inherently severe knowledge gaps.
  - Requirements are not well defined; end users are not involved and are often not available
  - Integration issues are vague, unknown or considered “beyond scope”
  - Subject Matter Experts (SME) with full system experience are not identified and available
  - The “context” for the S&T is not defined; an end application may not be clearly identified

# Achilles Heel of S&T Investment

## . . . is development without Capability

## Case in point:

**"A few years ago we had the problem of getting an effect that required a small kinetic warhead [to detonate] within a few feet [of the target]," he says. "We had the platform, the delivery vehicle and a weapon with enough accuracy. What we did not have was the [communication] pipes to get information because nobody had thought through the end-to-end, system-of-systems acquisition piece."**

Fulghum, David A., Mysteries and Secrets: If you do not know about it, China Lake has it, Aviation Week & Space Technology, September 28, 2009, p66.

# System Definition

- Performs one or more functions
- Created by integrating independent elements with their own functions
- Occupy a continuum from Simple to Complex
  - Mechanical writing implement
    - Marking element (lead, ink)
    - Extension-retraction mechanism
    - Holder (housing and grip)
    - Corrector
  - Aircraft (system of systems)
    - Airframe Structure
    - Propulsion
    - Avionics
    - Flight control "system"
- In the S&T realm, systems usually have not been defined
  - Breakdown structures help establish system context for targeted warfighter capabilities

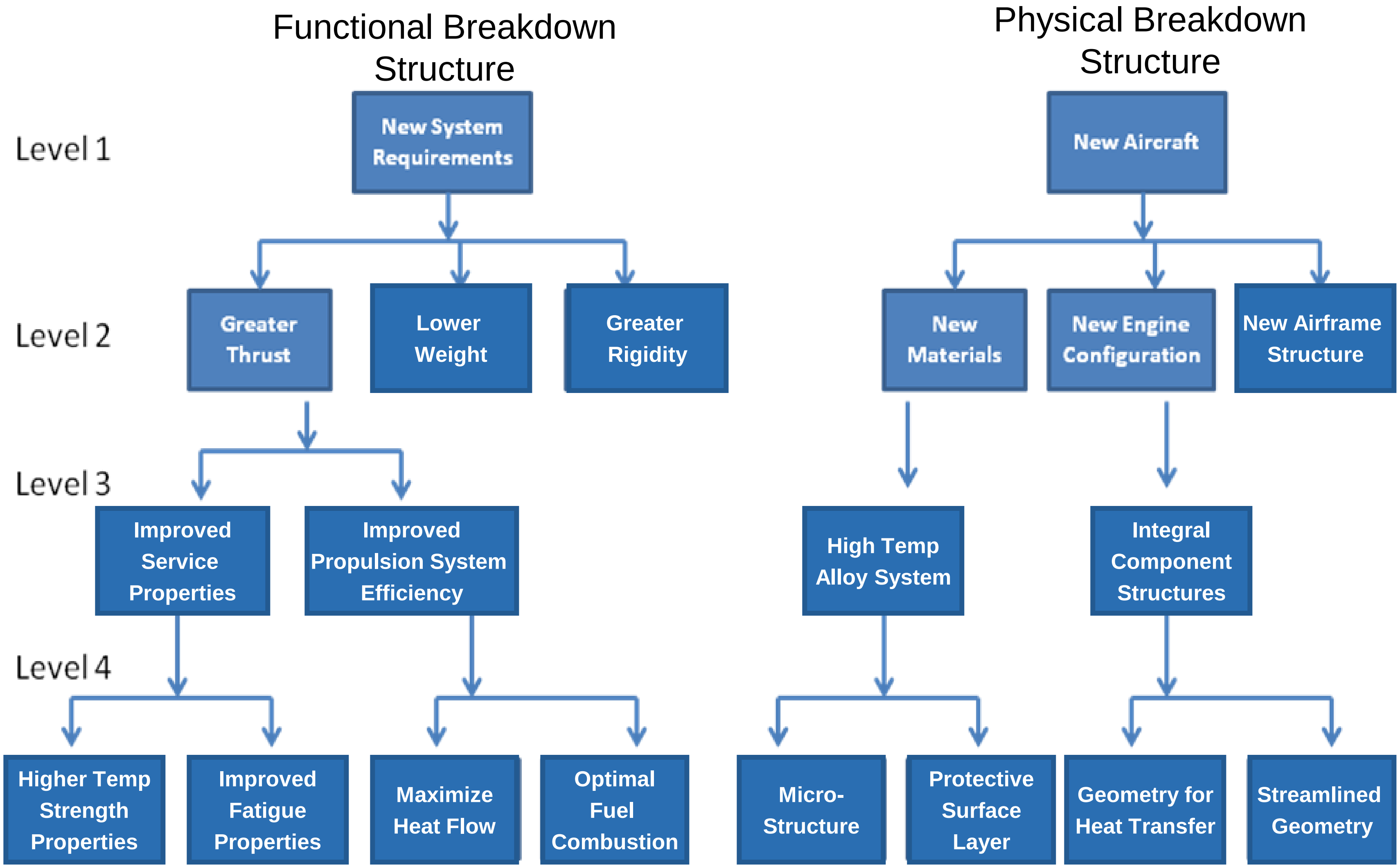
# System Decomposition

- A breakout, usually hierarchical, of the functional elements of a system
- *Functional*, not product or solution based
  - Example: directional control versus a ship's rudder

Ship electrically driven propulsion pod, rotates 360˚, no rudder, eliminates need for tugs

- Functional view of "system" is desired for S&T development
  - Avoid bias toward prior state-of-the-art or fascination with specific technologies that have limited application potential
  - Drive toward solutions that effectively address functional needs

# Illustration: Improved Aircraft Capability



# Semantics

- ***Functional decomposition*, *functional allocation*, *functional hierarchy*, *work breakdowns structure (WBS)*, and *system architecture* are often used interchangeably.**
- **Intent must be inferred from context**

# System Decomposition Techniques for S&T Development of Warfighter Capabilities

- **Functional Breakdown Structure** helps stimulate innovative and new solutions (which is fundamentally important to S&T work)
- **Physical Breakdown Structure** helps modify and improve solutions
  - Tool for identifying touch points and systems integration issues.
  - Tool for identifying Critical Technology Elements which are essential for Tech Readiness Assessments.
  - Tool for cost estimations. It is the Engineering approach. Other approaches are heuristic, parametric, and statistical approaches.
- **“Hybrid” WBS** captures key elements and not necessarily relationships between or among those elements.
  - Hierarchical purity is unnecessary and the time spent may be counterproductive in the S&T stages if a “systems” view is in the future.
- System Decomposition Techniques can be valuable SE tools for faster, more effective technology transition

***Tailoring SE Tools for Science and Technology***

# Streamlined Systems Engineering for S&T

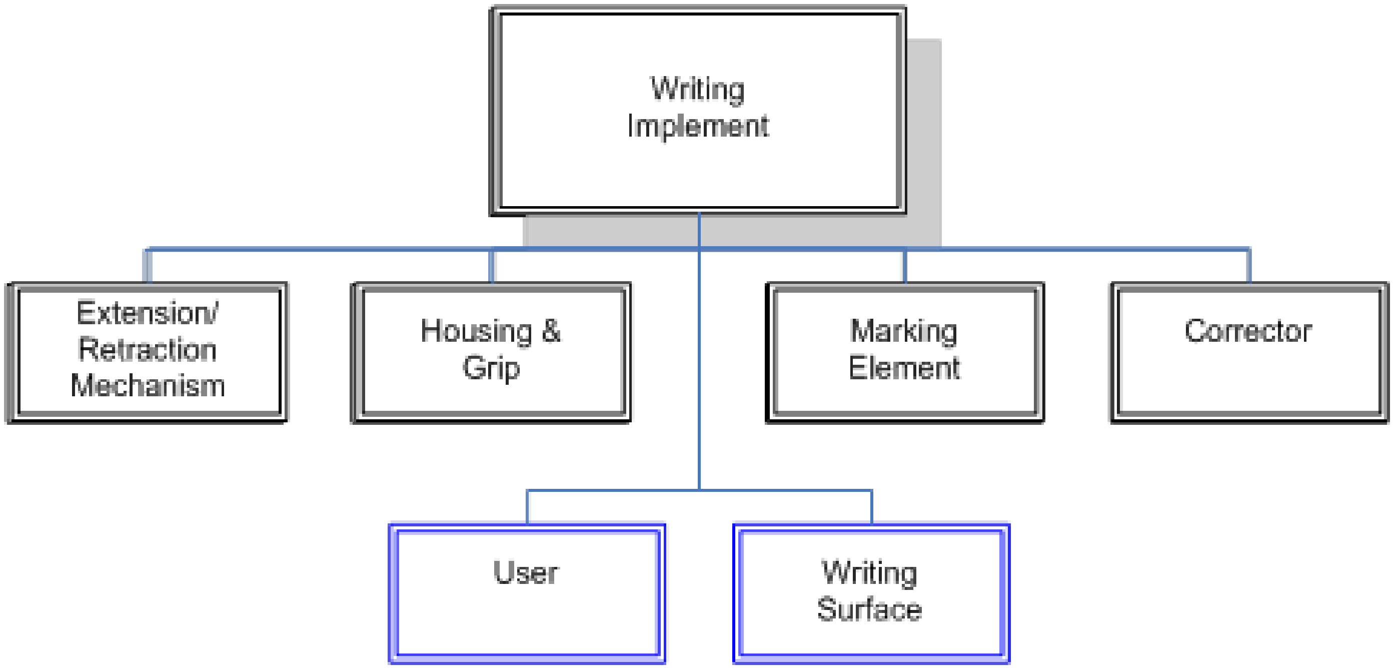
| | Step 1 | Step 2 | Step 3 | Step 4 | Step 5 |
|---|---|---|---|---|---|
| | ***Form Team*** → | ***Determine Requirements*** → | ***Generate Alternatives*** → | ***Evaluate Alternatives*** → | ***Deliver S&T Plan*** |
| **Do:** | • Define Problem<br>• Identify all stakeholders<br>• Establish Team | • Define requirements<br>• Define tech challenges<br>• Define S&T Exit Criteria (KPP sets)<br>• Validate with customer | • Understand applicable state-of-the-art & near term technologies<br>• Brainstorm different solution approaches | • Compare alternatives across Reqt's / S&T Exit Criteria<br>•Solicit Customer approval for proposed solution | • Finalize AF Problem / Goal / Solution Objectives<br>• Prepare for intended action course |
| **Document:** | ❑ Problem Definition<br>❑ Team Directory (includes roles & responsibilities)<br>❑ Team Charter (Optional) | ❑ Prioritized Requirement Set<br>- Performance Set<br>- Affordability<br>- Producibility<br>- Reliability<br>- Supportability<br>❑ S&T Exit Criteria | ❑ Alternative Definitions | ❑Tech Readiness Assessment (TRA)<br>❑ Manufacturing Readiness Assessment (MRA)<br>❑ Risk Analysis<br>❑ Value Analysis<br>❑ Cost Estimate<br>❑ Schedule / Key Milestones | ❑ AF Problem / Goal / Solution Objectives statement<br>❑ Program Roadmap<br>❑ Action Plan |

Hybrid WBS Evolves
Helps Identify Requirements & Alternatives

# Simple Example – First Pass

## First Pass – In S&T Too Often
## The "System" Context Is Ignored

# Writing Implement - Expanded



# Practical Example – Off-Grid Electrical Power

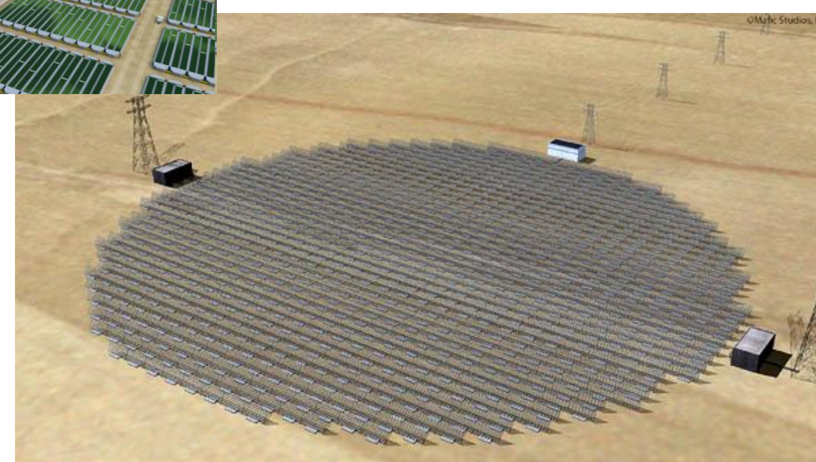
**Given**

- Supply electrical power to a remote location that does not have access to a power grid
- Minimize the need for transported fuel
- Has to be reliable
- Flexible enough for any location
- Has to be scalable to the end use

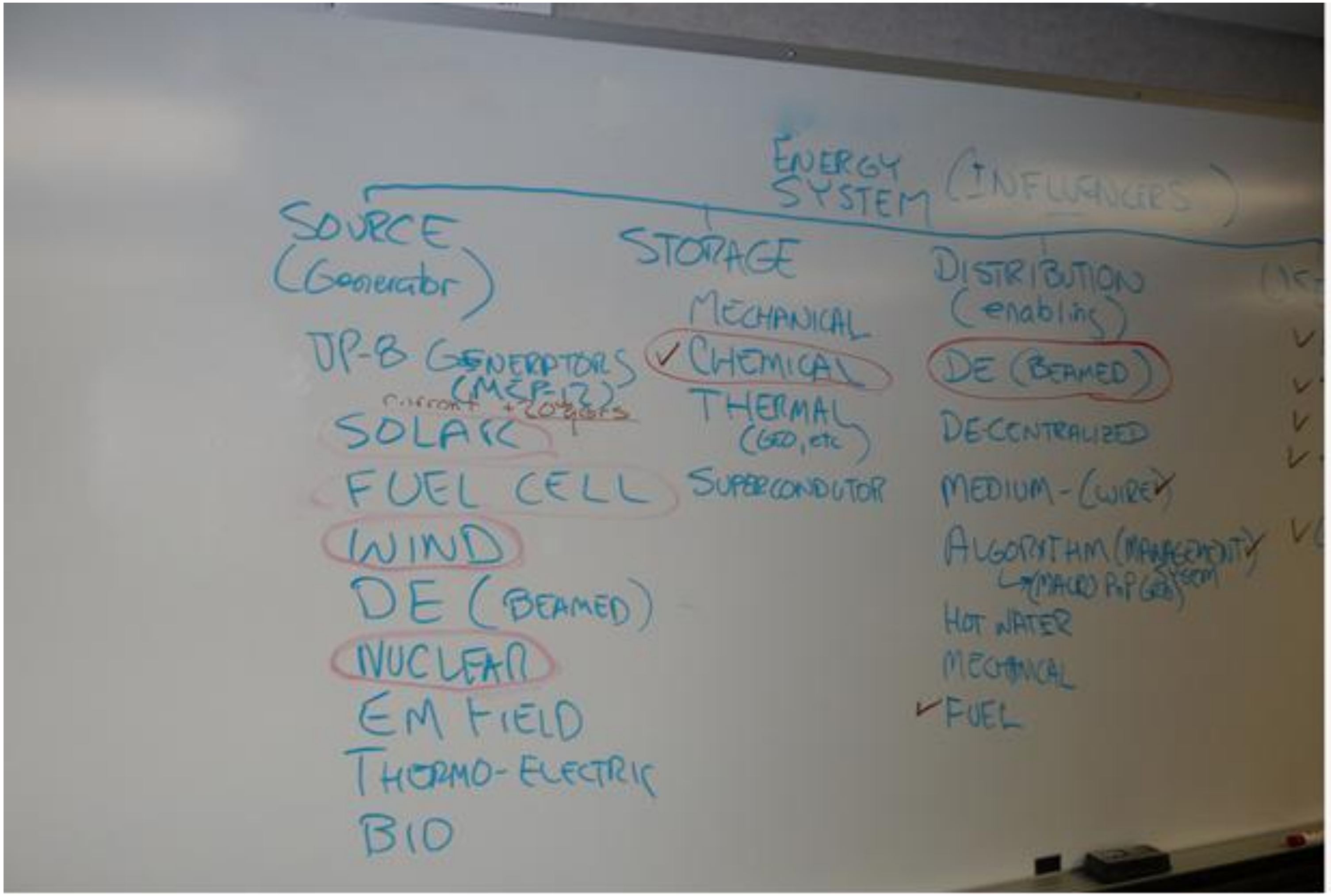
**Not Known**

- Load requirements or profiles
- Problems with current technology
- Logistics expectations
- System integration issues
- …. Don't know what we don't know?

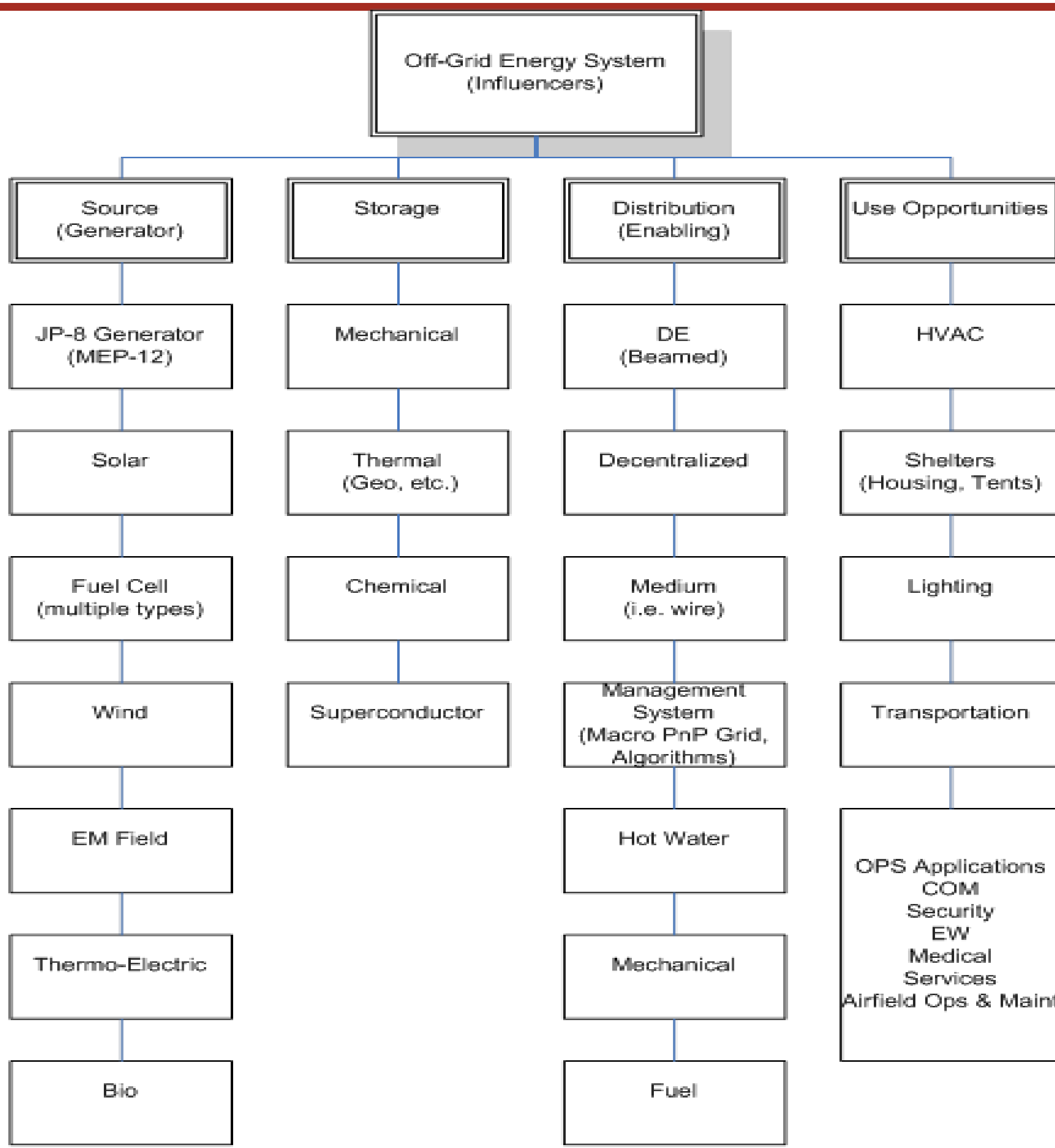
# Practical Example – Off-Grid Electrical Power
# Initial Discussion – Technology “Advocates”



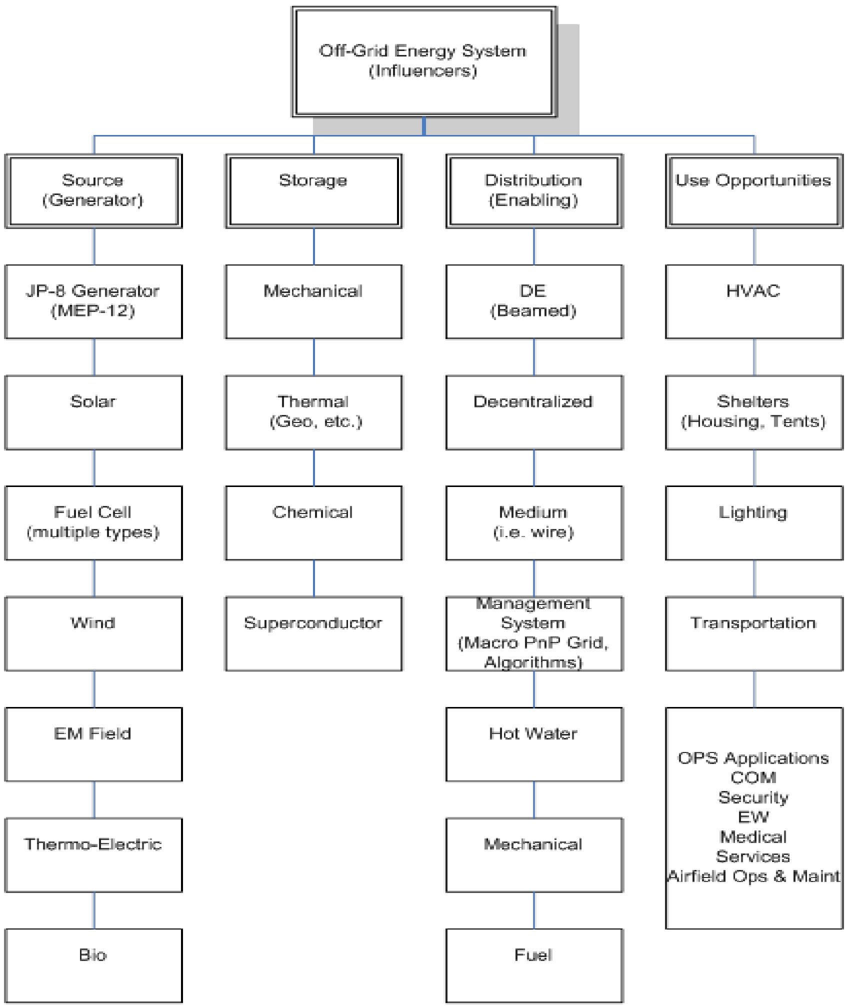
# Initial Working Session with SMEs

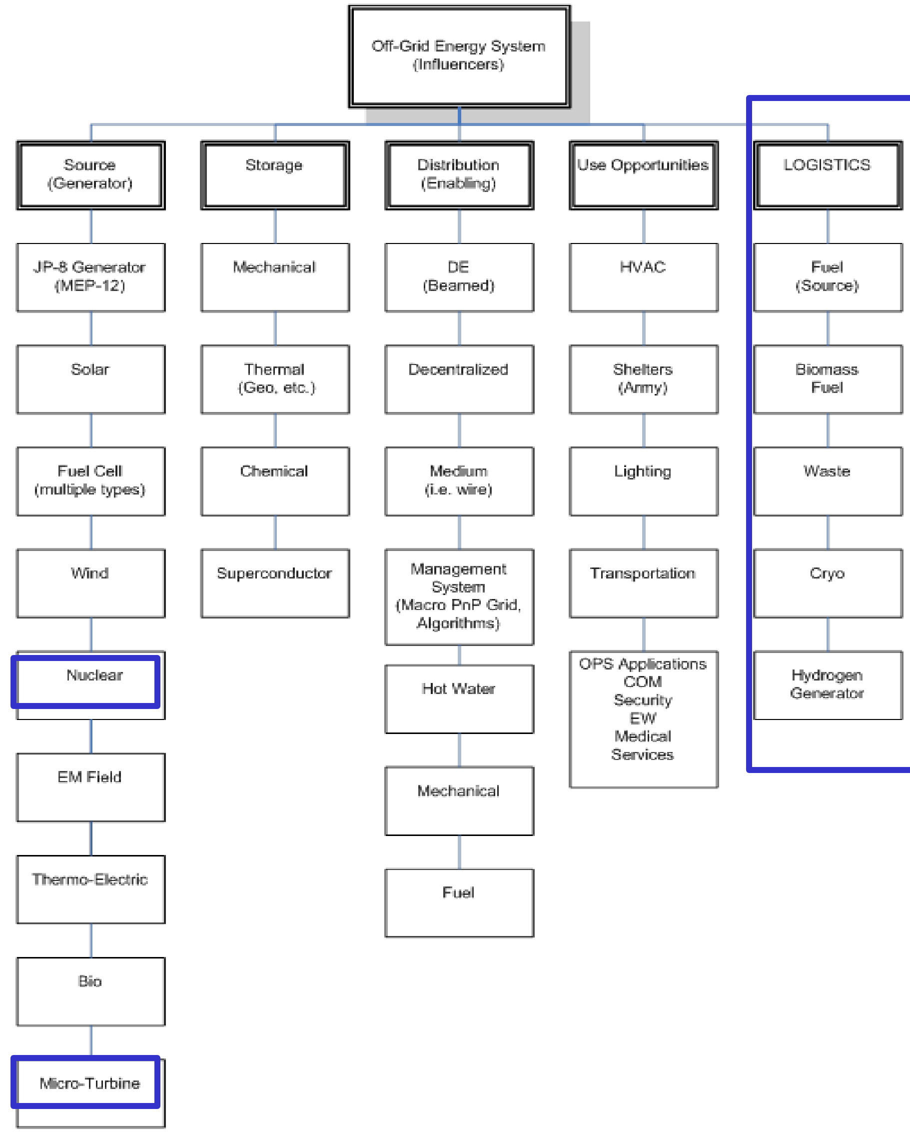


# Off-Grid Energy System 1st Pass



# Off-Grid Energy System – 1st & 2nd Pass



# Off-Grid Electric Power: Before & After Perspectives

| BEFORE (preliminary thoughts) | AFTER |
|---|---|
| Micro Turbines immature, limited utility | Mature technology, multiple commercial vendors, efficient, quiet, near drop-in |
| Power integration and management is a necessary evil largely addressed commercially | Critical enabling technology partially addressed commercially, required regardless of power source including local grid |
| Fuel cells (type not distinguished) very efficient, perhaps when mature a small panacea | PEM type dismissed as inadequate for power, solid oxide type is quiet, but may not be inherently more efficient after power conversion, more promising with heat recovery but has many in-use limitations |
| Solar with thermal concentrator not on initial list | Emerging technology in commercial use in Europe |
| Nuclear package ruled out as politically impractical | Limited commercial development may change political acceptance, better understanding of benefits |
| Space-based beamed energy not on initial list | Already under study by National Security Space Office |
| Photovoltaics assumed promising | Fails most criteria, huge costs and deployment problems |
| Biodiesel assumed promising | Fails most criteria, huge costs and deployment problems |
| Wind turbines | Fails most criteria, huge costs, cannot be air deployed |

# Conclusions

- This applies to S&T; actual system design requires more rigor.
- The hybrid WBS captures key elements and not necessarily relationships between or among those elements.
- Hierarchical purity is unnecessary and the time spent may be counterproductive in the S&T stages if a "systems" view is in the future.
- It takes a team of Subject Matter Experts (SMEs) to create an effective hybrid WBS.
  - There is a low probability that one person, particularly an S&T specialist, can create a valuable WBS.
  - It is easy to create a perfunctory and useless WBS; it takes more work to provide game changing value.
- The WBS should be revisited frequently as the S&T matures through TRLs. The more interest in the S&T, the more important the WBS and its revelation of potential obstacles to applying the S&T.
- The WBS can be the first step in assuring the value and timeliness of S&T for future warfighter capabilities