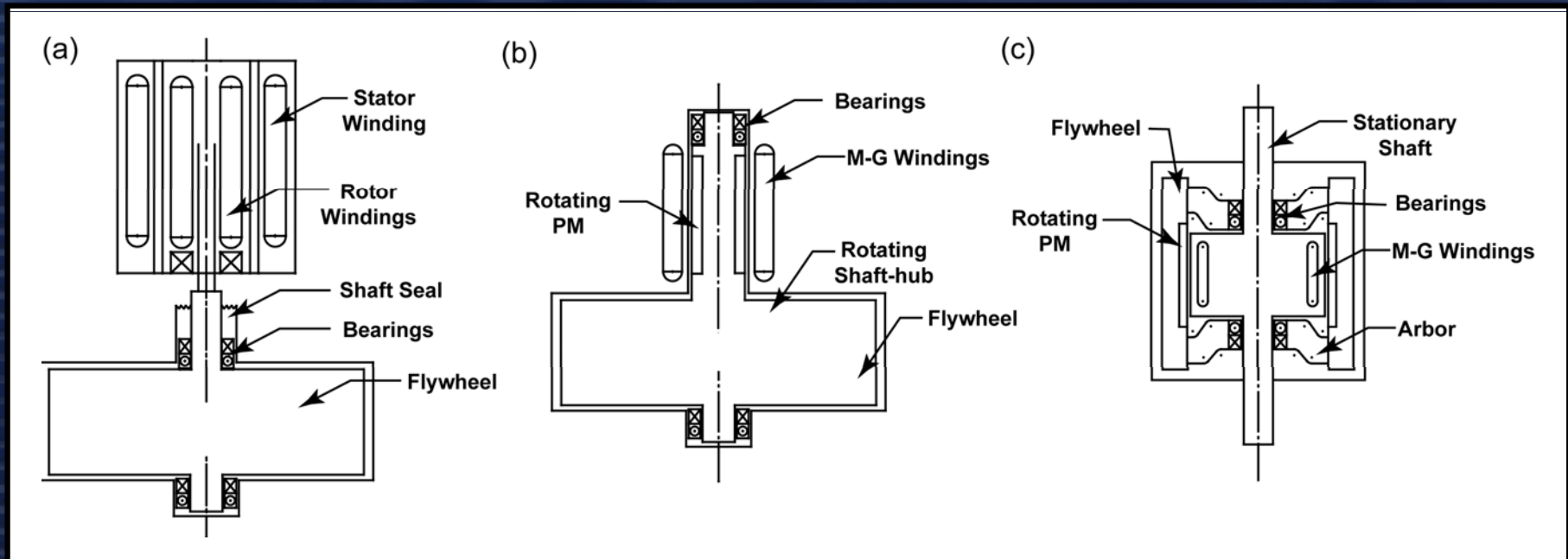


Kinetic Energy Storage and Power Generation

**Bob Hebner
University of Texas**

Kinetic Energy Storage

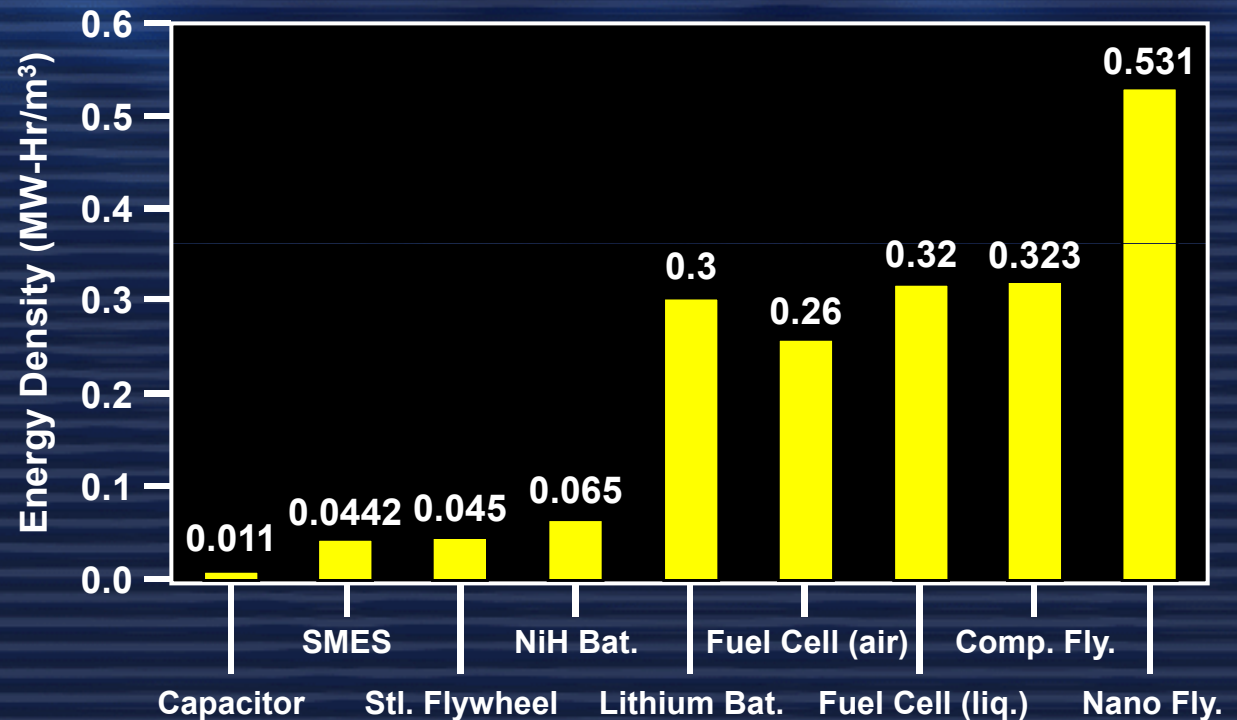
In kinetic energy storage, power and energy are separate design choices



Idealized Comparisons

Fundamental
limits to maximum
energy density for
various energy
Storage
approaches

Energy Density Comparison



**Suggests that chemical and kinetic energy storage
have high energy density**

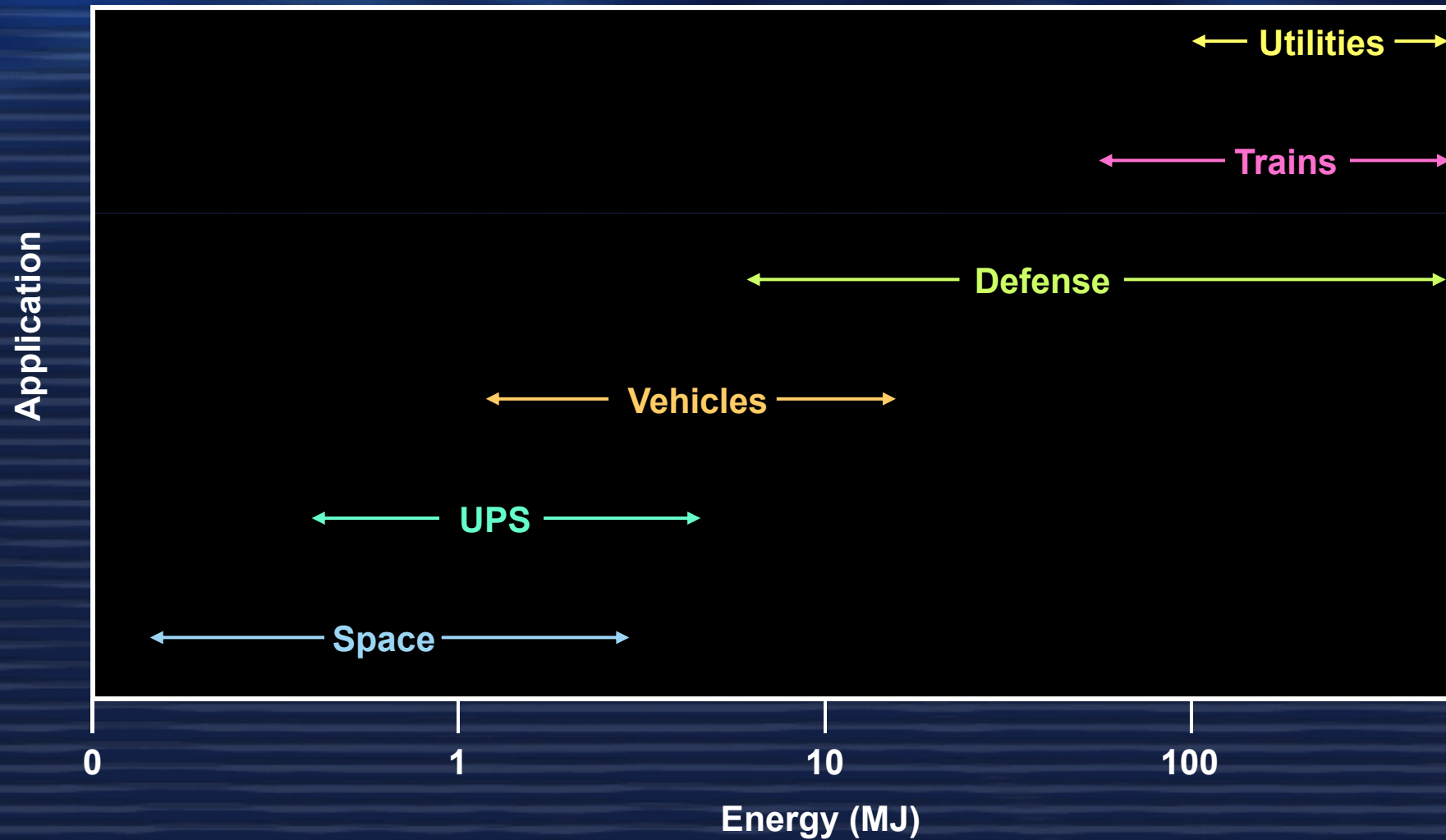
Pragmatic Considerations

- The best technology may not be the short term driver.
- Approximate order of research investment:

Fuel cell > Batteries >> Inertial \approx Electrical > Magnetic

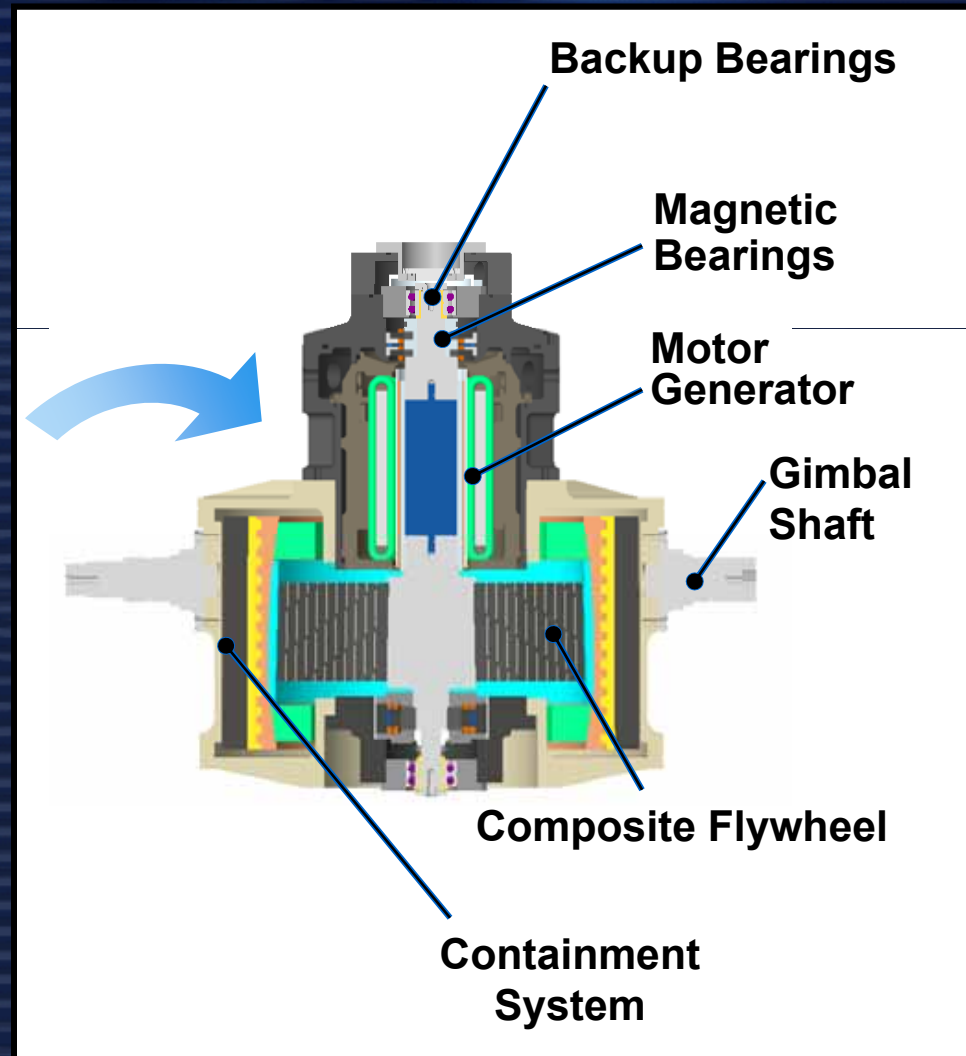
Research investment will limit technology choices

Range of Applications Leads to Range of Sizes



Flywheel Highlights

- Conducted flywheel tests, including
 - Flywheel-only tests to identify failure modes and structural margins
 - Flywheel burst tests to test candidate containment designs
- Demonstrated life of more than 110,000 cycles with a 50% DOD



Flywheel Spin Tests

- **Flywheel tests to-date:**
 - **Numerous burst tests (modified design for containment proof tests)**
 - **Loss of vacuum test**
 - **Overspeed “As Built” Test**
 - Preload loss
 - 1120 m/s
 - Benign and recoverable
 - **Fatigue tests**



Technical Success - Flywheel

- New record speed for composite flywheel assembly (1.4 km/s)
- Key features
 - Composite arbor design
 - Quality fabrication



Largest Composite Flywheel

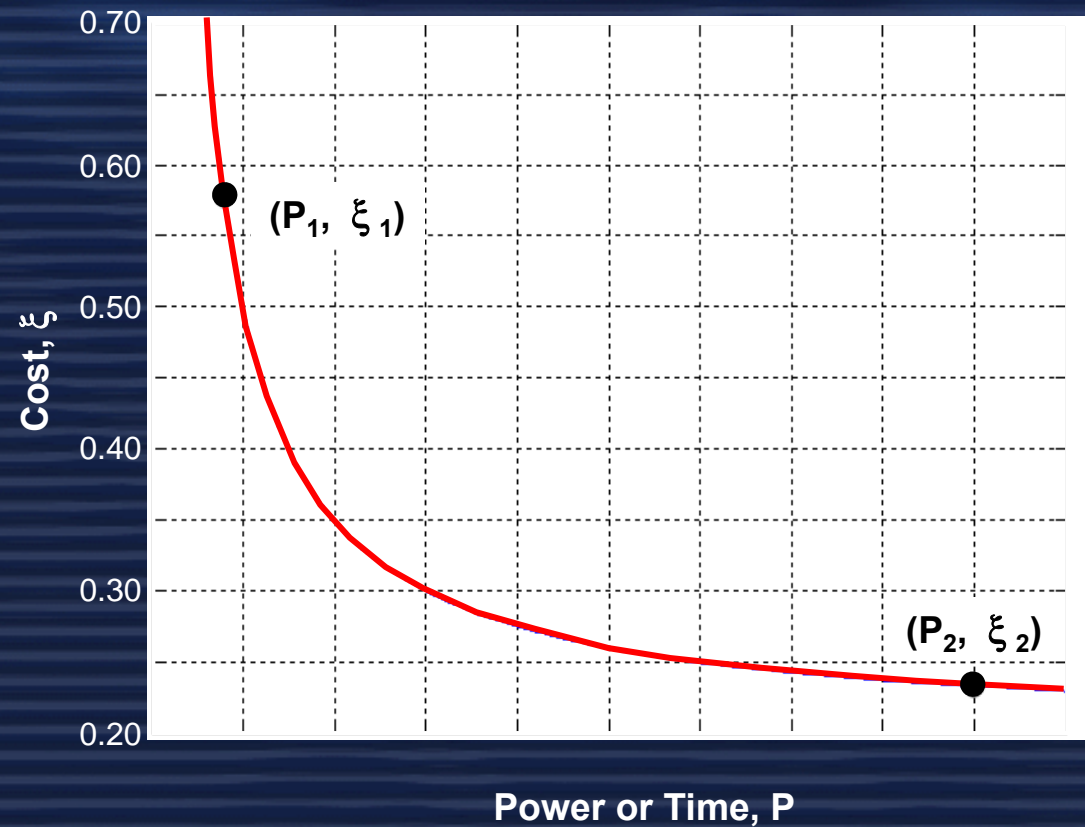
- ~ 500 MJ
- 15,000 rpm
- 2 MW for 3 minutes
- Testing with high input and output power



Approach to System Issues

For storage to be economical, \$ (stored) < \$ (generated)

Cost to produce power and the cost of energy storage are both complex functions.



Economic Considerations

Analysis Relates:

$$\begin{array}{c}
 \text{Generation costs} \\
 \underbrace{\hspace{10em}} \\
 ((\xi_1 / \xi_2) - 1) > \\
 \beta^{-1} \underbrace{(\text{Energy loss}) / \text{Energy stored}} \\
 \text{Storage parameters}
 \end{array}$$

Turnaround efficiency for kinetic energy storage >> for batteries

Remaining kinetic challenge: Energy loss

Research Opportunity

- **Achieve minimal loss for 12 hours +**
 - **Superconducting bearings**
 - MRI systems make cryo-coolers robust commercial devices
 - Research promising
 - Experiments needed to guide future research
- **Success opens door reliable use of intermittent generation sources**
 - **Wind**
 - **Solar**
 - Either off or on grid

Conclusions

- **Kinetic energy storage is a viable alternative to chemical storage for high energy density needs**
- **Kinetic energy storage is being used today in niche markets**
- **Additional research and development could exploit the high turnaround efficiency to improve energy storage and usage**