Innovative Automobile Materials Technologies: "Feasibility" As An Emergent Systems Property

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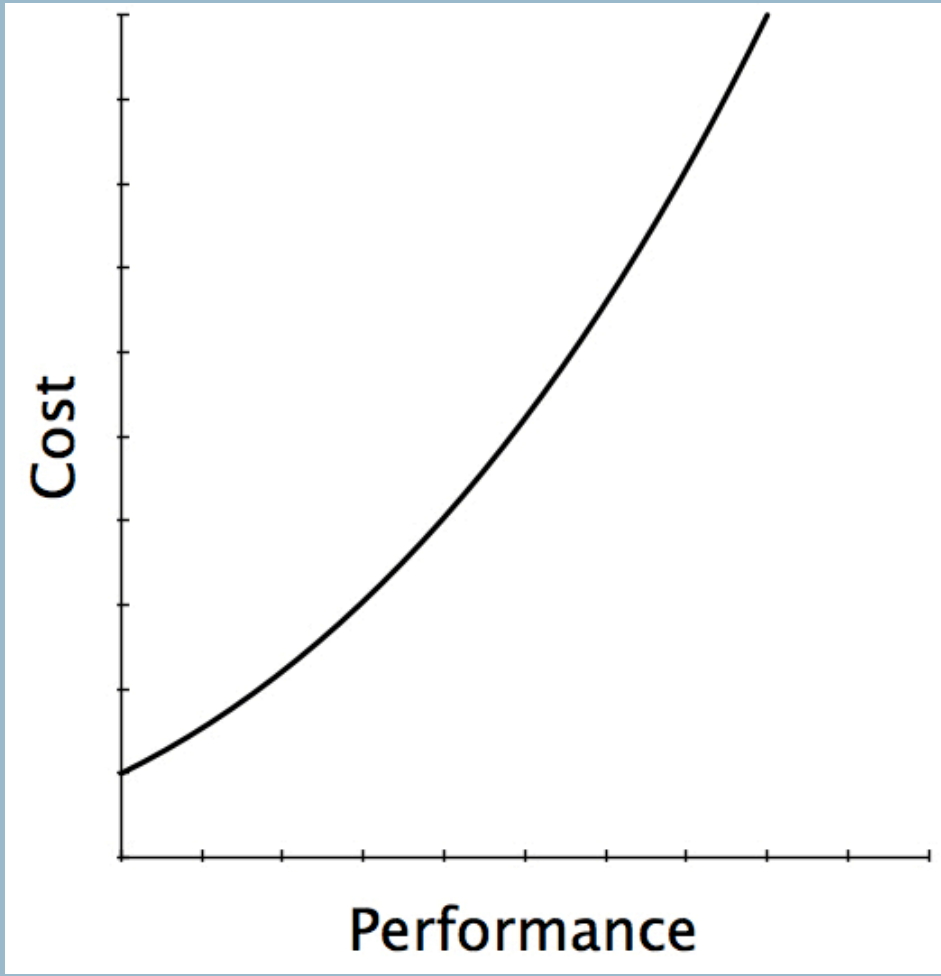
Realizing Lightweight Vehicle Designs

- Many possible approaches and technical options
- But fundamental obstacles
  - Not all (or even largely!) technical
- There's "can do" and "can afford to do"
  - Or "technically feasible" and "feasible"
- The latter is trickier

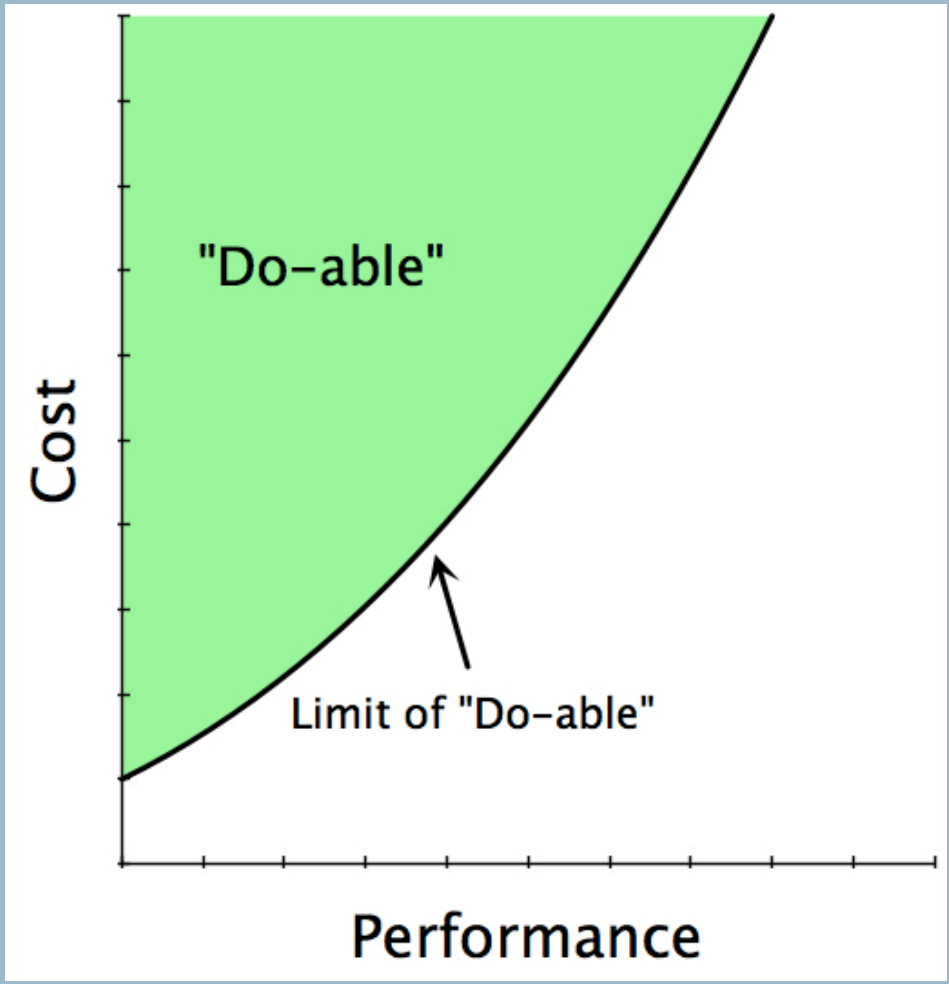
Notions of "Feasibility"

- **Convention: A limit to performance, constrained by cost**
- **Upward sloping, meaning an upper limit to performance**
- **Defined by technological options**



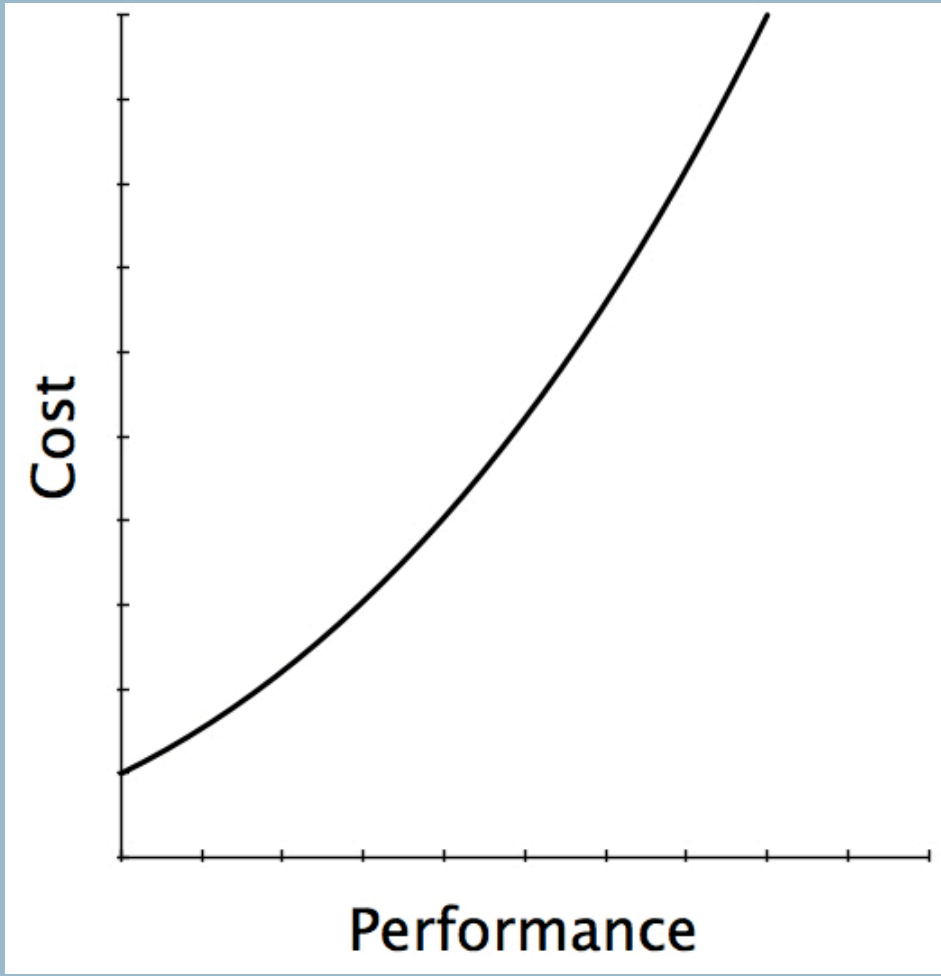
A "Technical Frontier"

- Defines a boundary between what can be done and what can't be done
- Would expect to find real cases in the green region
- Interior points
  - Tradeoffs among different kinds of performance



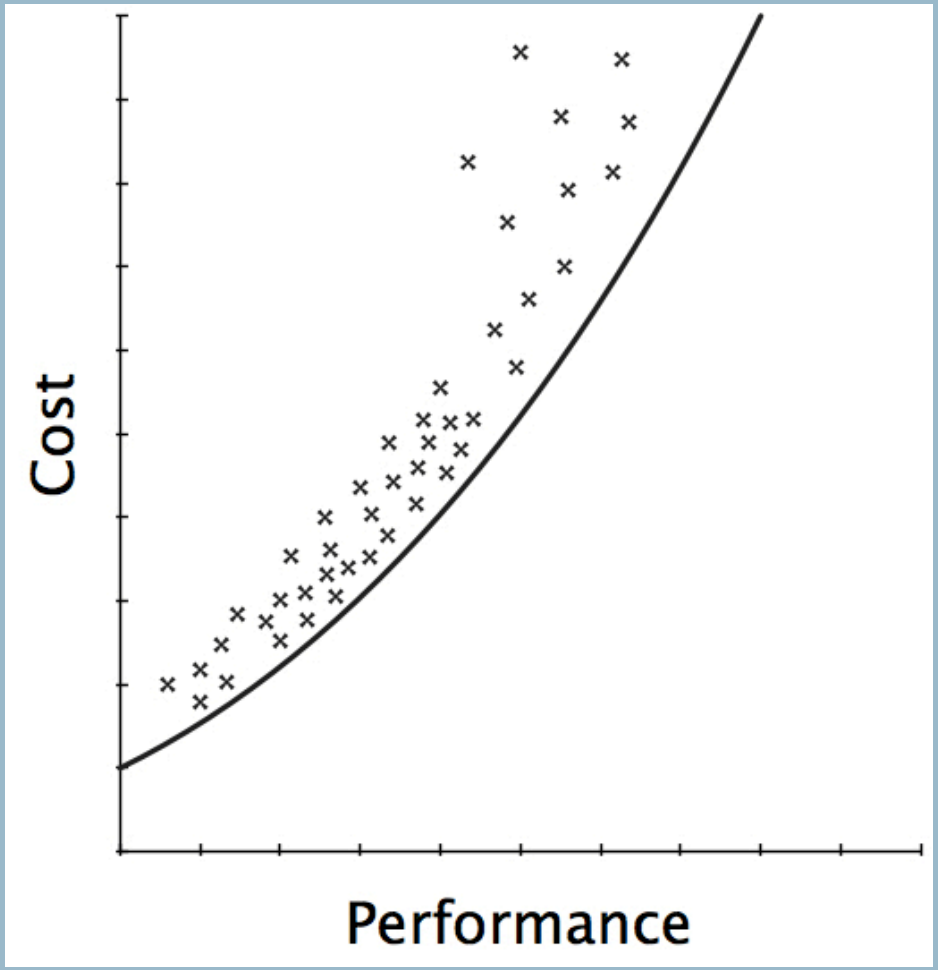
Finding This Boundary Is Difficult

- Analyses can be undertaken
- But, for complex products, purely technical derivations cannot be done
- Normative assessments based on observations



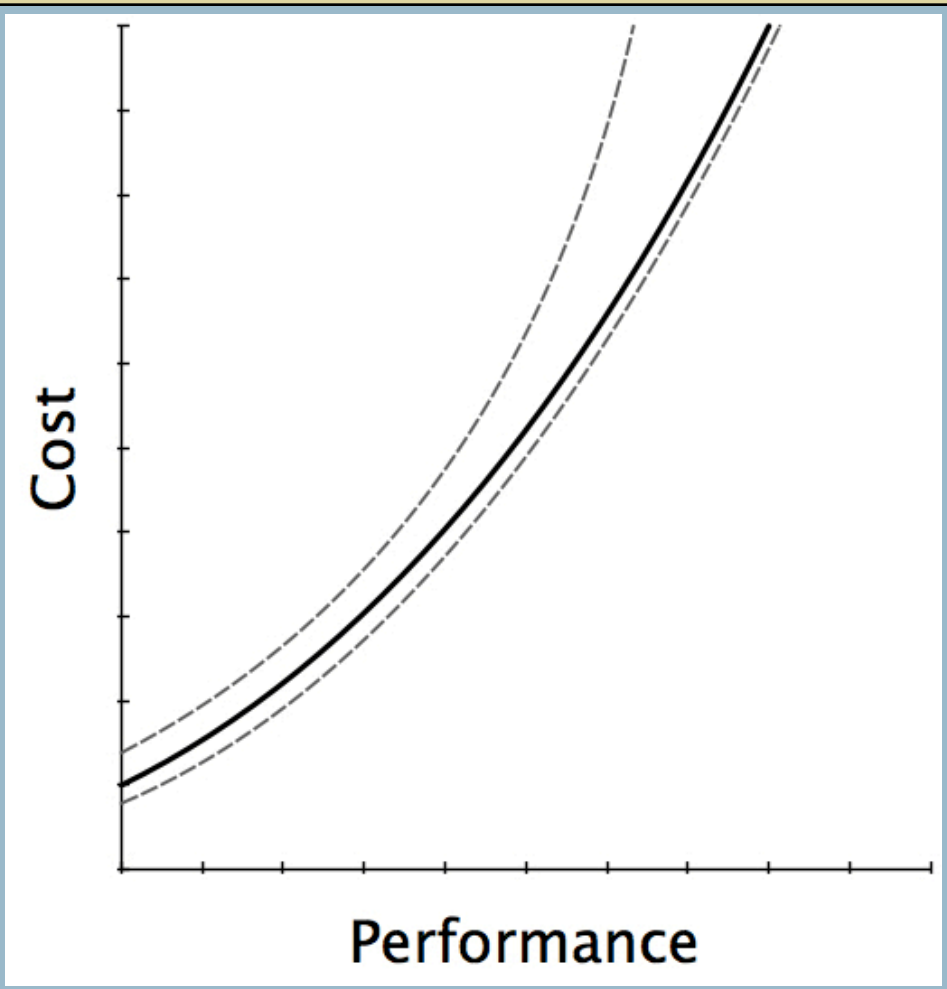
A Typical Scatter

- Tight cluster of observations in regimes of widespread application
- Sparse and scattered observations in regimes that stretch limits



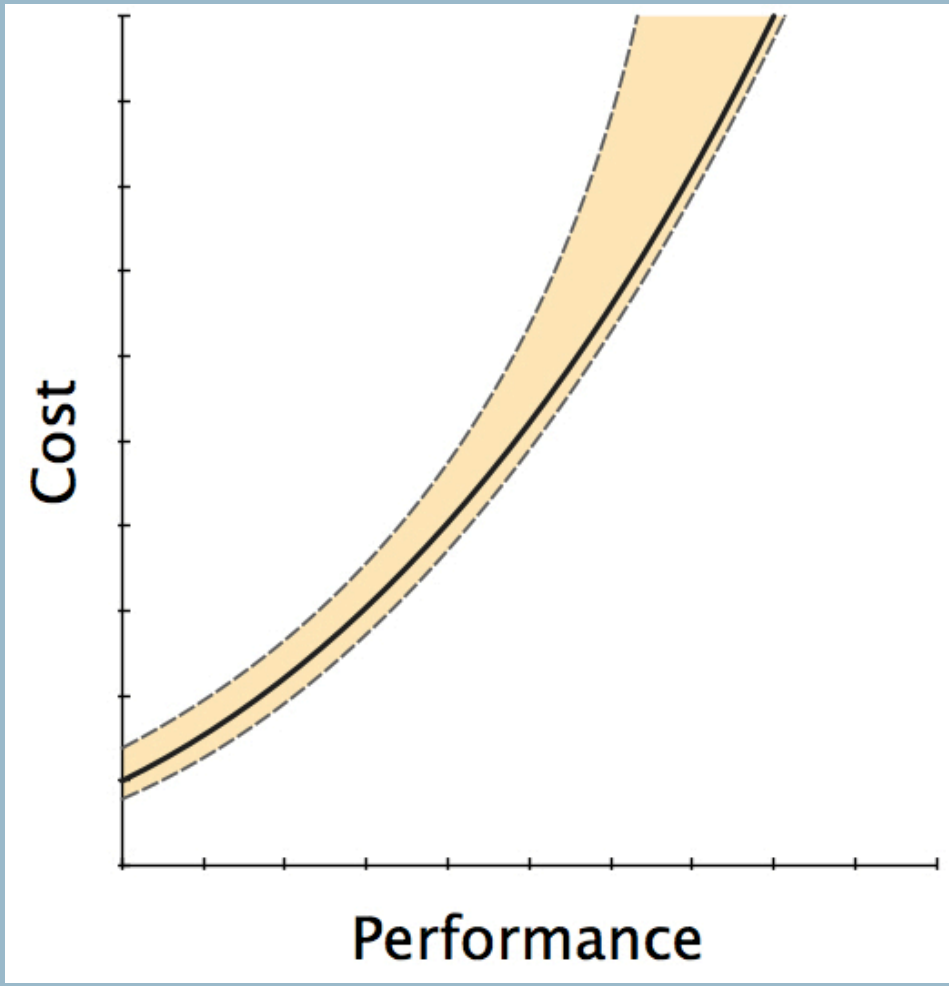
A Band of Uncertainty Around An Estimated Frontier

- Tighter in regimes of common use
- But wider as performance is extended
  - Reliance upon systemic features, interactions, etc. to achieve higher performance
  - Harder to predict & control
  - Less likely to be optimized for these complementary features



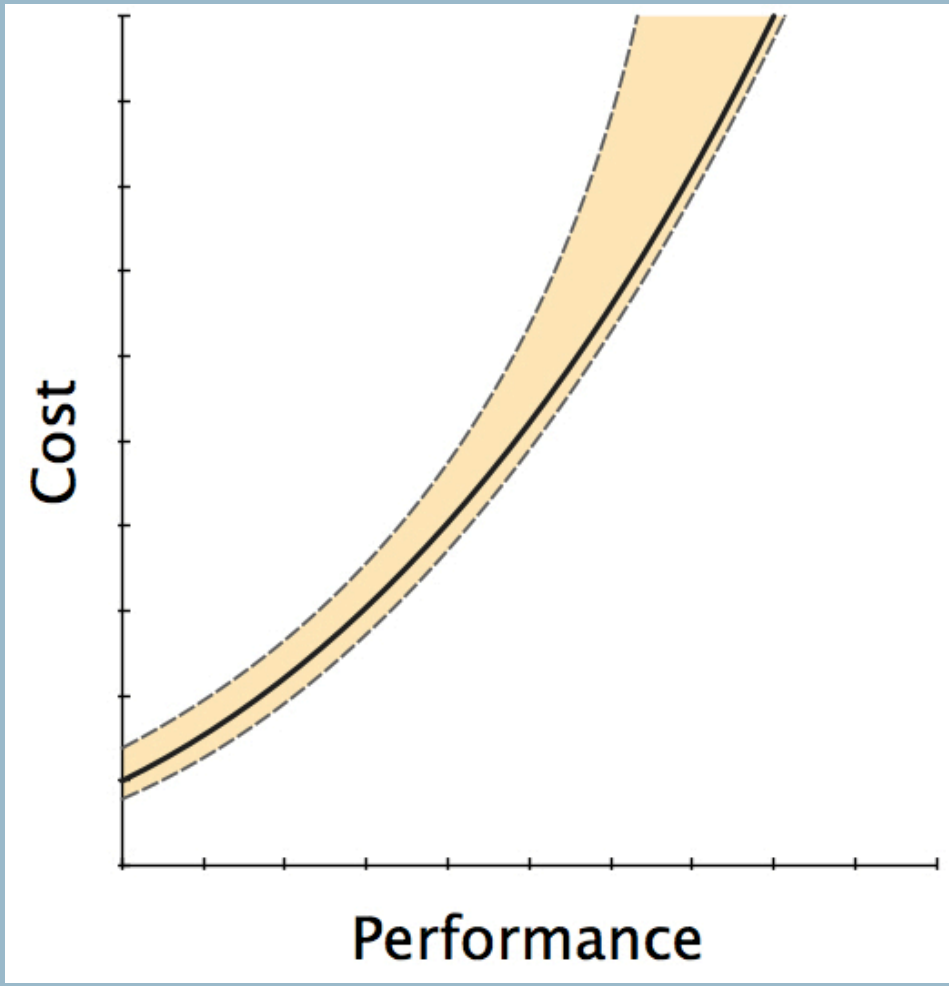
Additional Reasons for This Shape

- Promoters of high performance will tend to offer best case scenarios
- Institutional elements (supply chain, production facilities, etc.) tend to support mainstream



Implications for Analysis

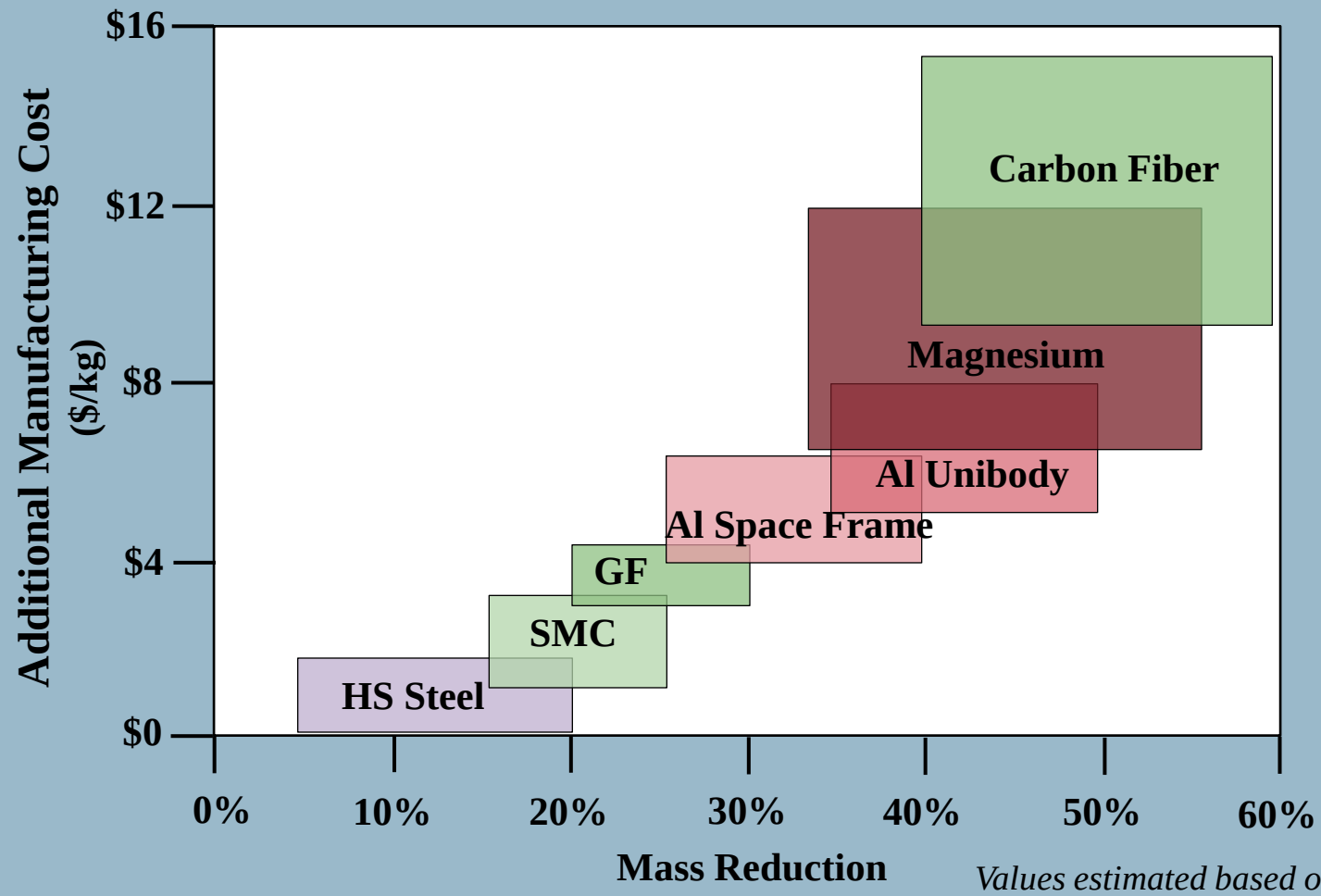
- **Unavoidable uncertainty suggests a different form of analysis as performance targets are increased**
- **Less about prediction, and more about contingencies**
  - **What is needed/has to happen to meet this cost/performance target?**
  - **And what results if these things do not come to pass?**
  - **And what can be done to better understand (or act to reduce) that risk?**



Lightweighting Options

- **Materials Technologies**
  - **High Strength & Ultra High Strength Steels**
  - **Aluminum**
  - **Magnesium and other "light metals"**
  - **Polymers**
  - **Reinforced Polymer Composites**
    - Glass, Carbon fiber
- **Demonstrated applications**
  - **Albeit, not all commercial**

Lightweight Vehicle Structures Generally Cost More to Manufacture



Values estimated based on a collection of MSL vehicle cost analyses and other sources

Lightweighting Is Strategic, Not Just Technical

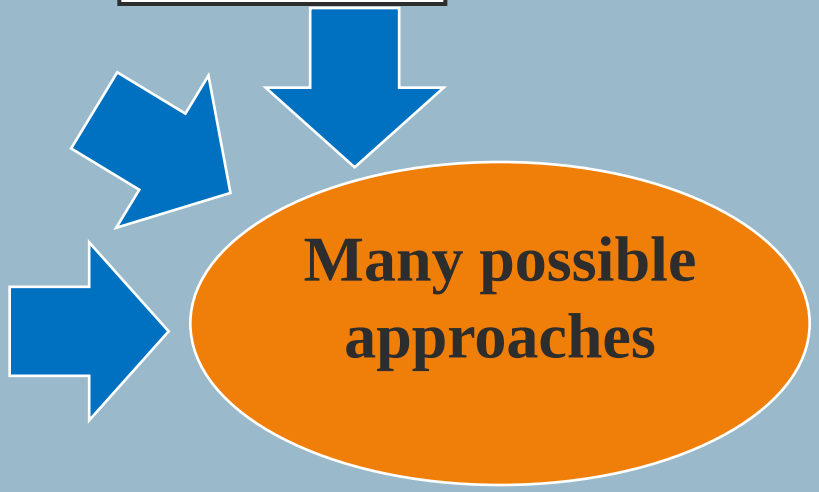
Vehicles:
- High/Low Volume
- Compact Cars
- Midsize Cars
- SUVs …

Materials:
- Steel
- Aluminum
- Magnesium
- Composites

Other:
- Paint
- Assembly
- …

Subsystems:
- Body
- Closures
- Chassis …

Processes:
- Stamping
- Molding
- Casting …



Consequence of These Realities

- **Rapid material changes if:**
  - **Overwhelmingly superior technology**
  - **Overconstrained design space**
  - **Disruptive market circumstances**
- **Typical materials selection strategies**
  - **NOT optimizing**
  - **Rather, satisficing**
    - too complex a decision space
    - many simplifying assumptions required

Obstacles/Hurdles

Technological

- **Manufacturability**
  - Forming
  - Assembly
  - Coating & Painting

Institutional

- **Design Tools & Methods**
- **Crash/Finite Element Analysis**
- **Installed Manufacturing Base**
  - Capital Investment Needs
  - Worker Experience

Supply Chain

Issue: supply base moves in response to demand, but demand is dampened by perceived supply limitations

- **Parts/subsystems**
  - Installed capacity & expertise
- **Materials supply chain**
  - Insufficient production of automotive grade materials
  - Materials availability concerns

State of Lightweighting Technologies

	Weight Saving	Technical Readiness	Institutional Change Needs	Supply Chain Readiness
Steels	Low – Medium	Current	Low	Current
Aluminum	Medium	Current – Near Term	Low – Medium	Current
Magnesium	High	Medium – Long Term *- some current applications* *Major issues:* *forming, coating, joining*	Medium – High	Materials: add'l supply needed Parts: add'l capacity needed
Glass Fiber Composites	Low – Medium	Current – Near Term	Medium – High	Materials: current Parts: add'l capacity needed
Carbon Fiber Composites	High	Medium Term *- some current applications* *Major issues:* *painting/coating, joining*	Medium – High	Materials: add'l supply needed Parts: add'l capacity needed

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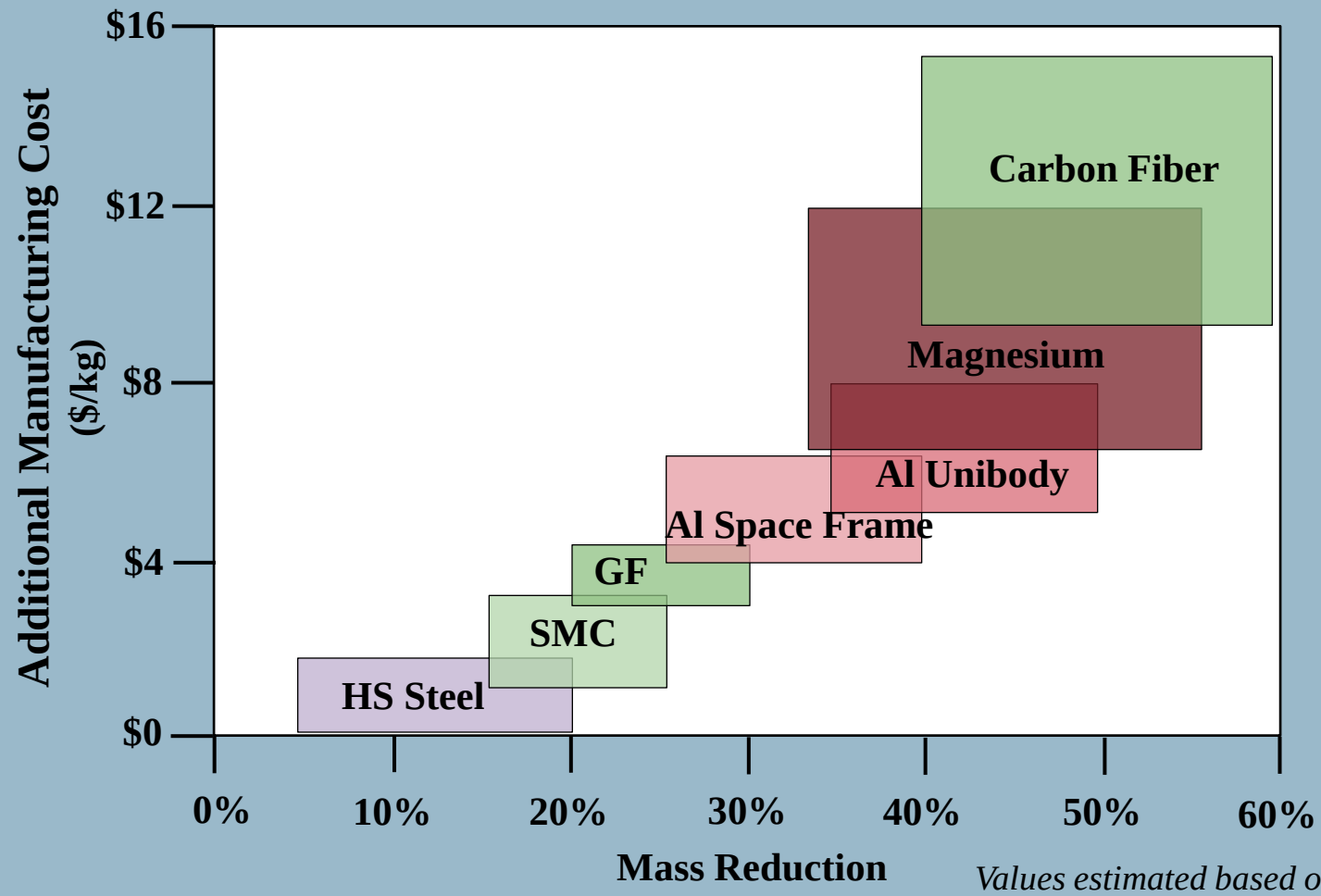

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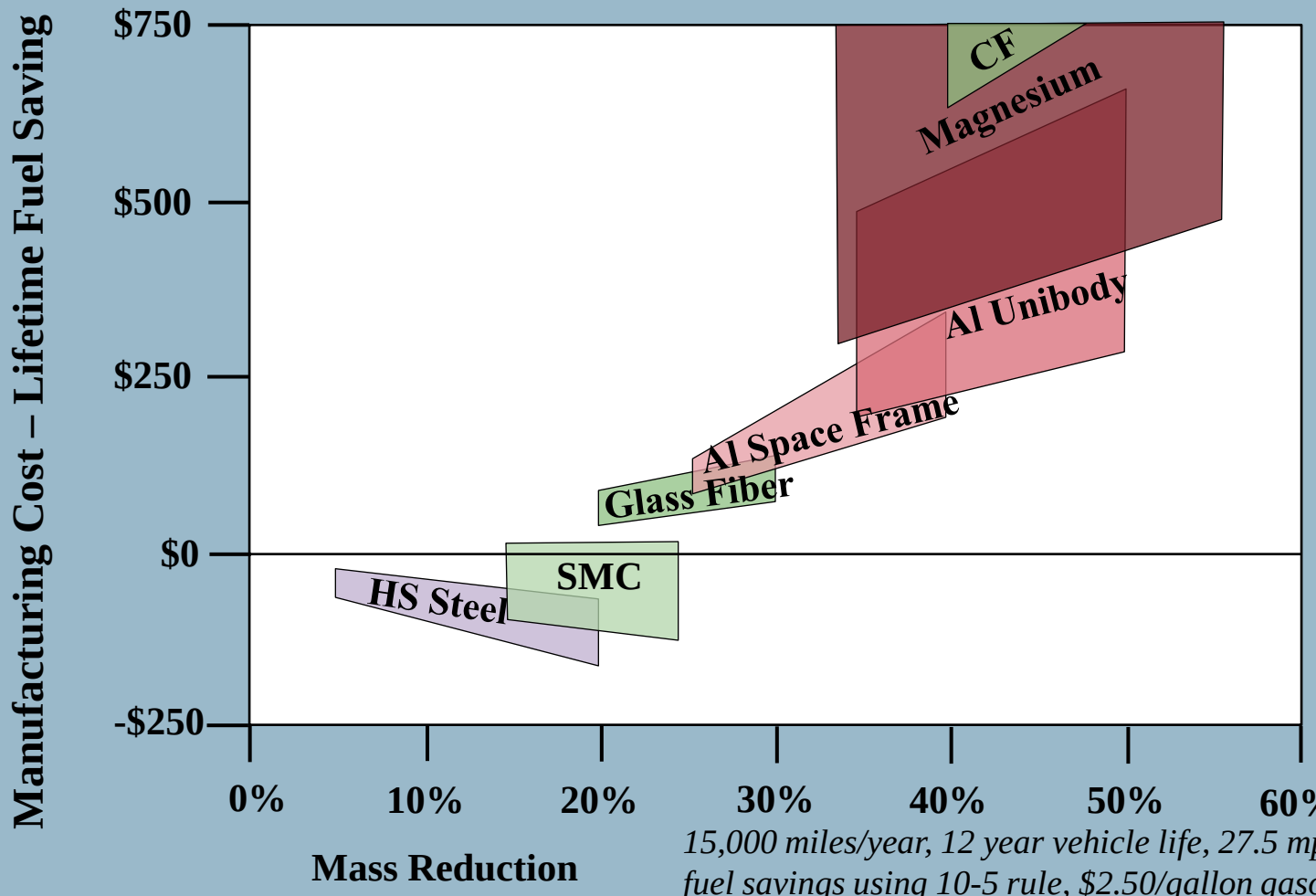
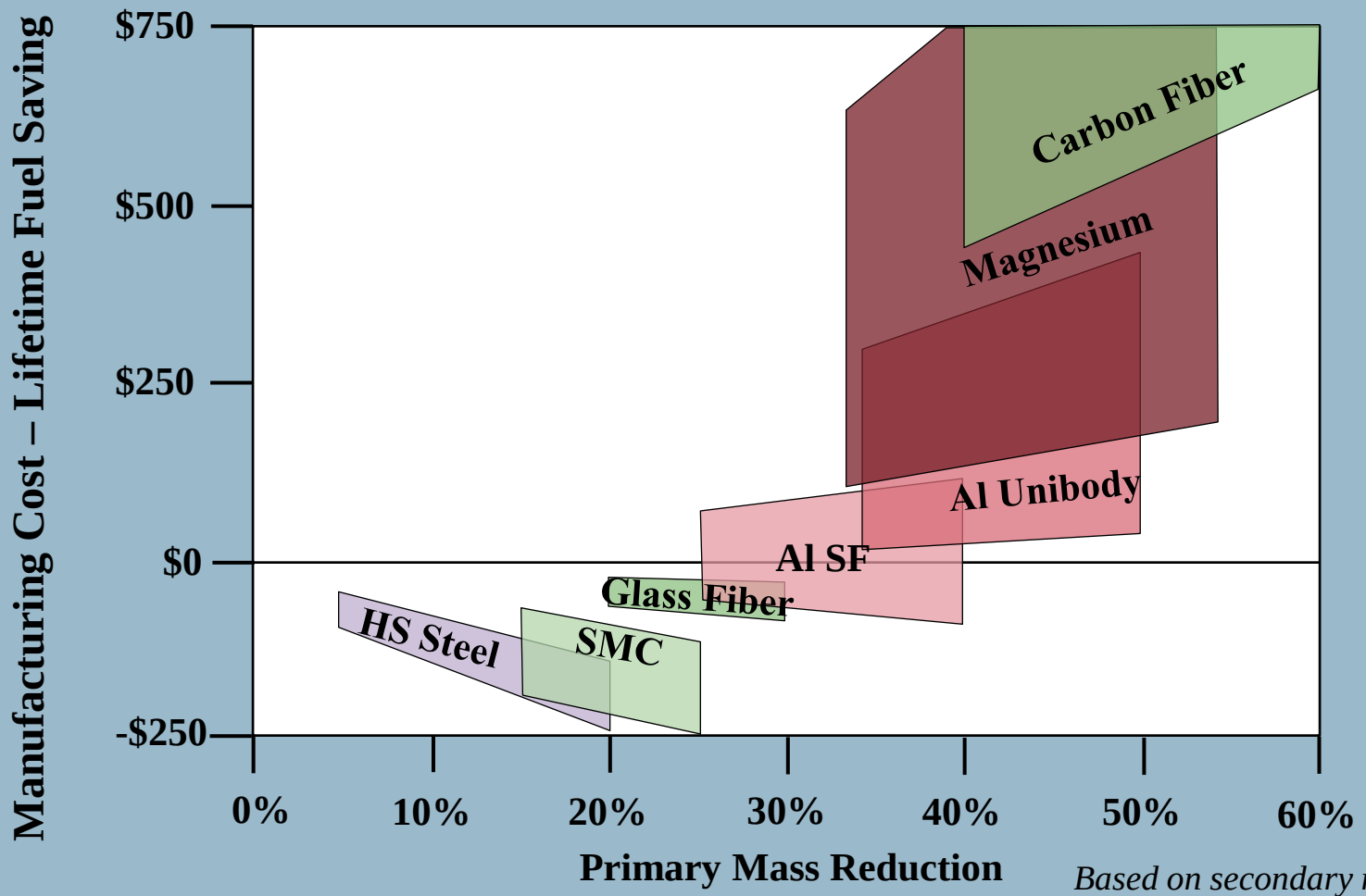
Lifetime Fuel Savings Generally Insufficient to Offset Manufacturing Costs



15,000 miles/year, 12 year vehicle life, 27.5 mpg base fuel economy, fuel savings using 10-5 rule, $2.50/gallon gasoline, baseline body mass = 250kg, vehicle mass = 1300kg, discount rate = 15%

Consideration of Secondary Weight Savings Improves the Case for Lightweighting



Based on secondary mass savings of 0.8kg for every 1kg primary mass saving

Wider Perspectives

- **Other factors may change that cost picture**
  - **Cost of assembly, processing improvements, more efficient processing, technological improvement, and so forth …**
- **But serious change demands a wider agenda**
  - **Coordination across the industry**
  - **A commitment to lightweighting roadmap**
    - Producers, suppliers, regulators
    - An environment for lightweighting innovation

Emerging Opportunity: Alternative Powertrains and Lightweighting

- **Use of "battery" enabled powertrains translate into severe limitations on vehicle weight in order to preserve vehicle range**
- **Two competing views of lightweighting**
  - **Why bother with too much lightweighting since larger fuel economy gains to be gotten from powertrain?**
  - **Lightweight as much as possible in order to reduce the size of the battery**
    - Reduced battery size leads to reduced cost which can usually more than offset the cost of lightweighting the remainder of the vehicle

Other Thoughts and Conclusions

- Mastering vehicle lightweighting technologies offers a path for growth in U.S. manufacturing and potential comparative advantage
- Technology improvements/manufacturing learning needed to ensure that lightweight approaches meet their cost targets
- Several lightweighting technologies look promising when viewed from a complete cost standpoint
- Advantages of lightweight vehicles greatly enhanced in vehicles with advanced (electric) powertrains
  - Most (if not all) technologies may be cost effective

Summary

Can Improved Fuel Economy Targets Be Achieved?

- Depends on the targets and the timing
- Careful consideration needed of the following:
  - Changes required to the installed capital base
  - Are skills/human resources sufficient for the transitions?
  - Rate of change possible within supply chain and OEMS
  - Can remaining technical challenges be overcome in a timely manner?
  - Overall cost impact
- "Technical feasibility" is NOT "feasibility"
- And achieving feasibility requires actively addressing the systemic issues