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A Realistic Thermal Mitigation Strategy for Solid Rocket Motors

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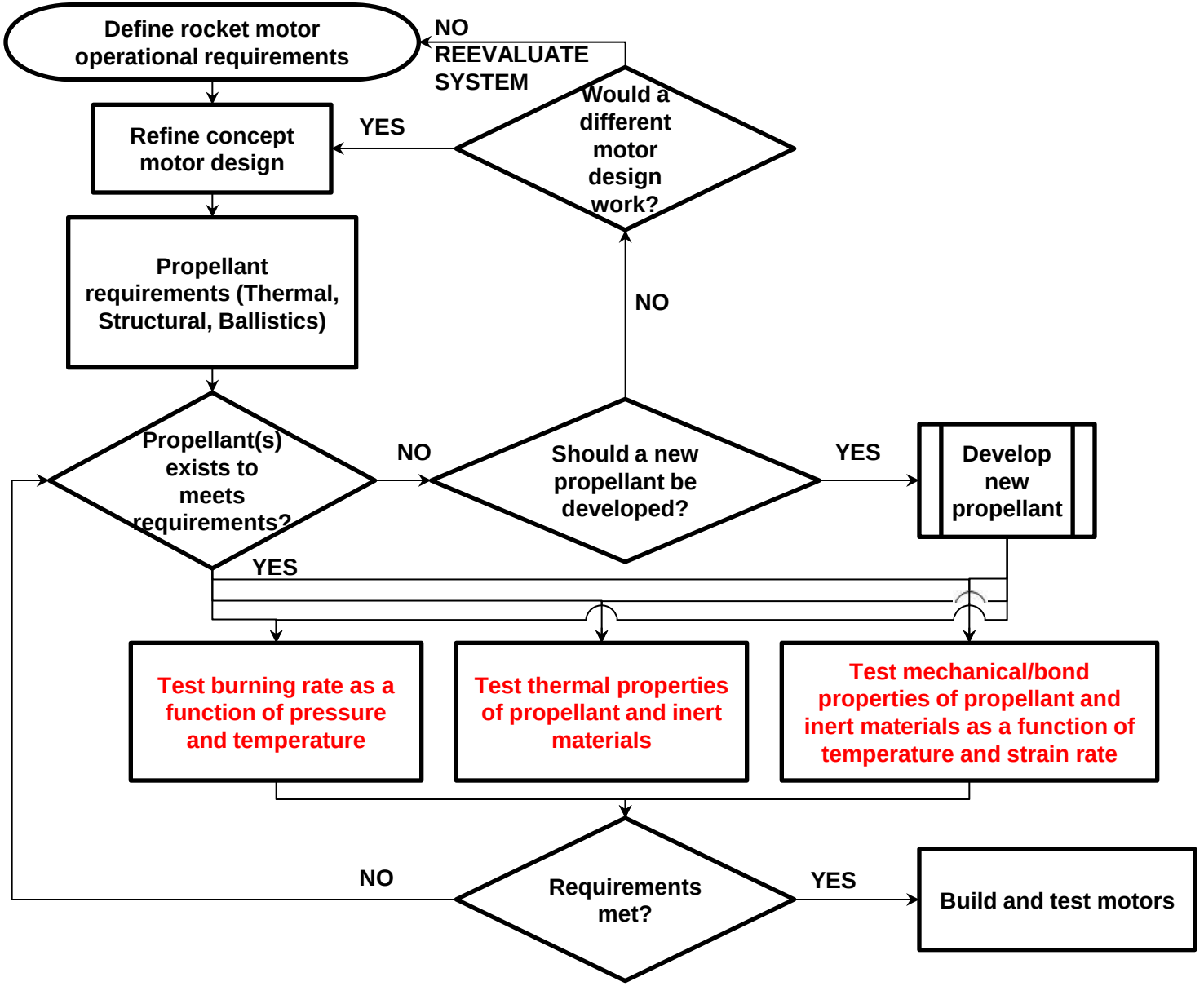
Outline

- **Background**
  - Description of the problem
- **A Path Toward Controlled Release of Energy**
- **Aerojet Propellant Testing**
  - Assessment of thermal properties
  - Assessment of burning rate
  - Assessment of mechanical properties
- **Summary and Recommendations**

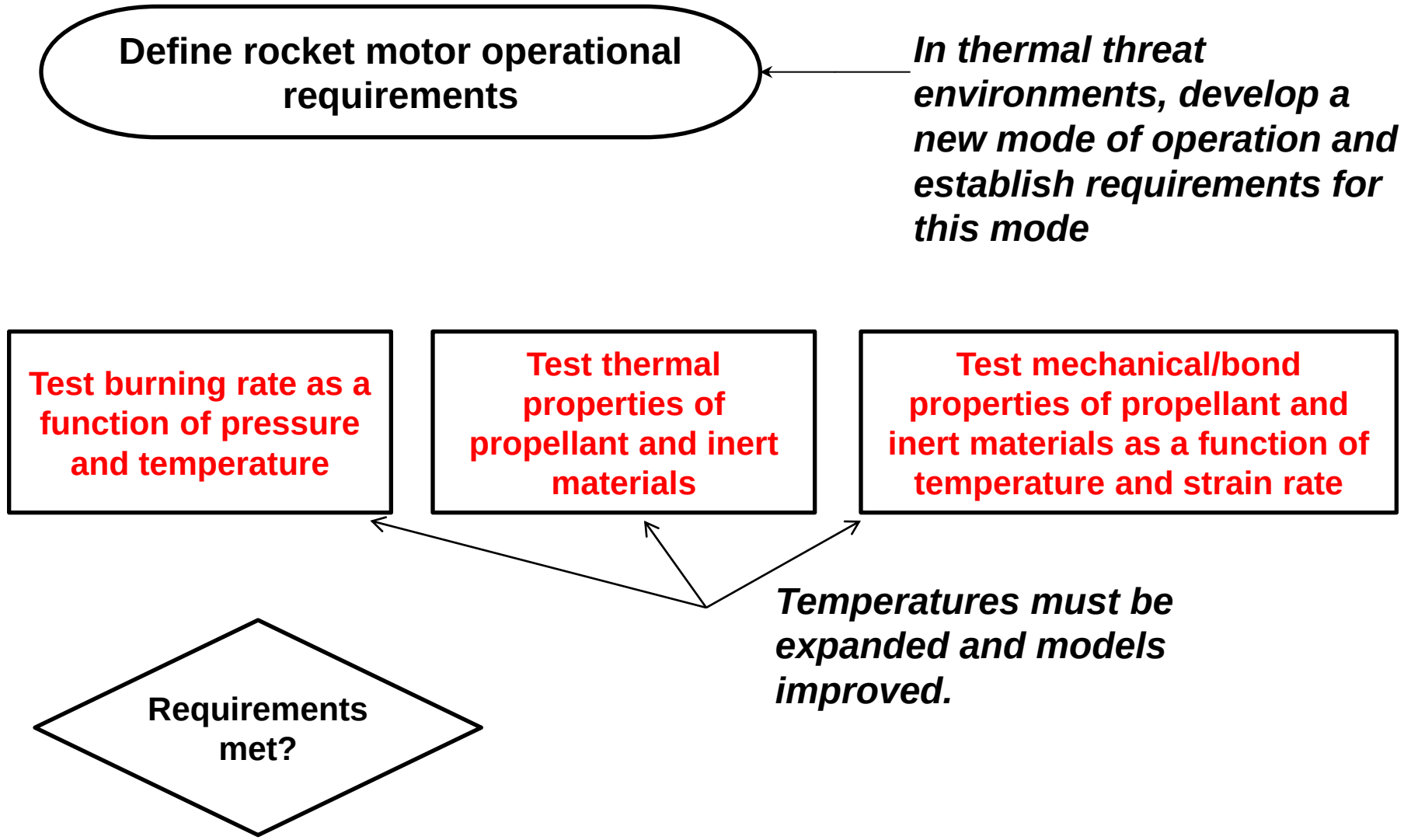
The Cookoff Problem

- **Solid Rocket Motors are, in essence, stored energy systems.**
  - **Enough heating will eventually cause the release of this energy.**
    - **Large motors contain a lot of energy**
  - **Faster heating (fuel fire) usually causes a surface ignition of the energetic material.**
    - **Most of the material in large motors remains near normal environmental temperatures.**
    - **Confinement can lead to drastically different results.**
  - **Slow heating often results in extensive damage prior to ignition.**
    - **Ignition occurs in the bulk, due to self-heating.**
    - **Hardness of the material in this damaged state can influence reaction by adding to confinement.**
    - **Large motors do not behave like small motors.**

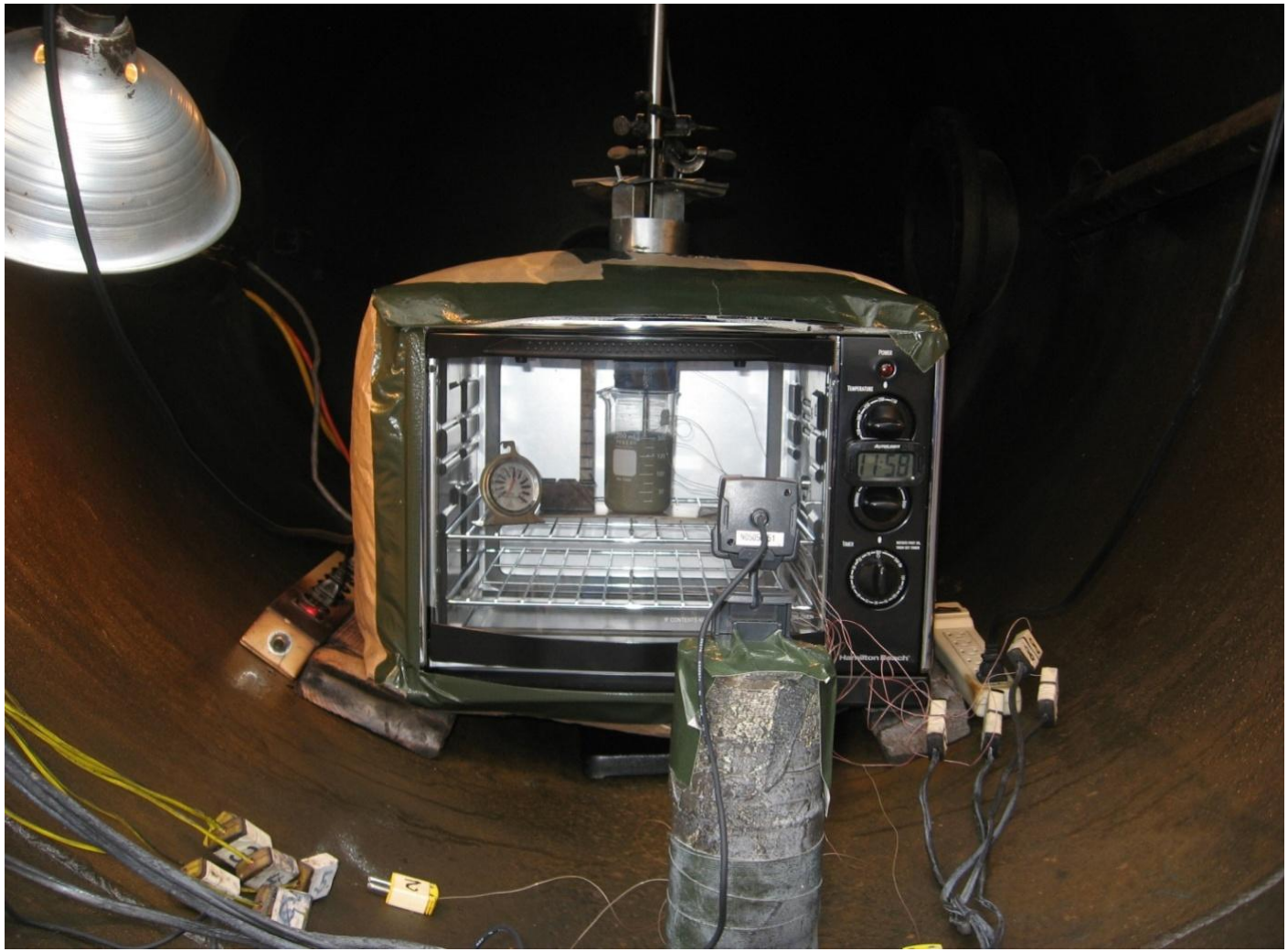
A Systematic Approach



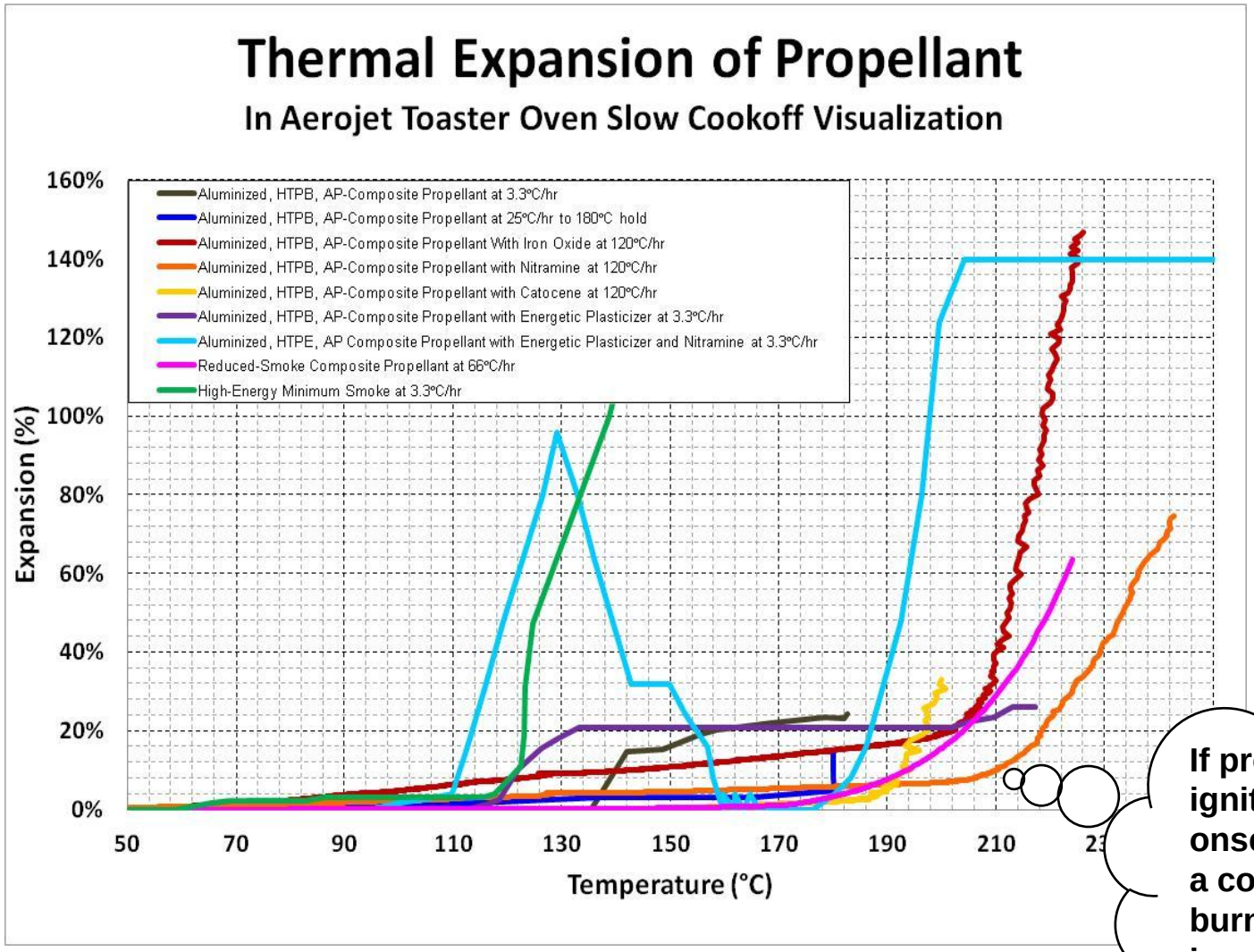
A Systematic Approach to Cookoff



Modified Slow Cookoff Visualization Test



Propellant Growth and Swelling



If propellant is ignited before the onset of swelling, a controlled burning reaction is achievable.

Propellant Burning Rates at Elevated Temperatures

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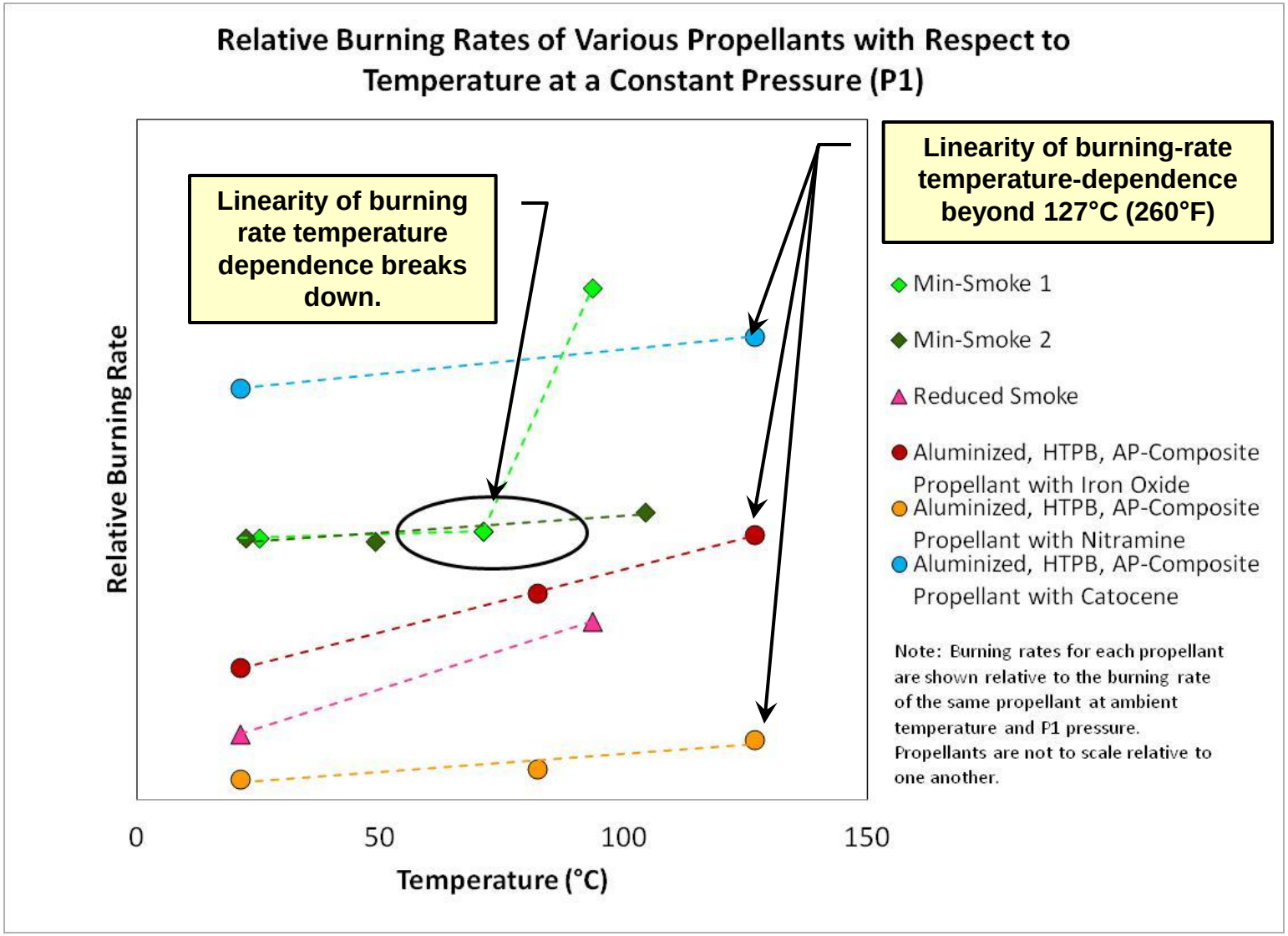

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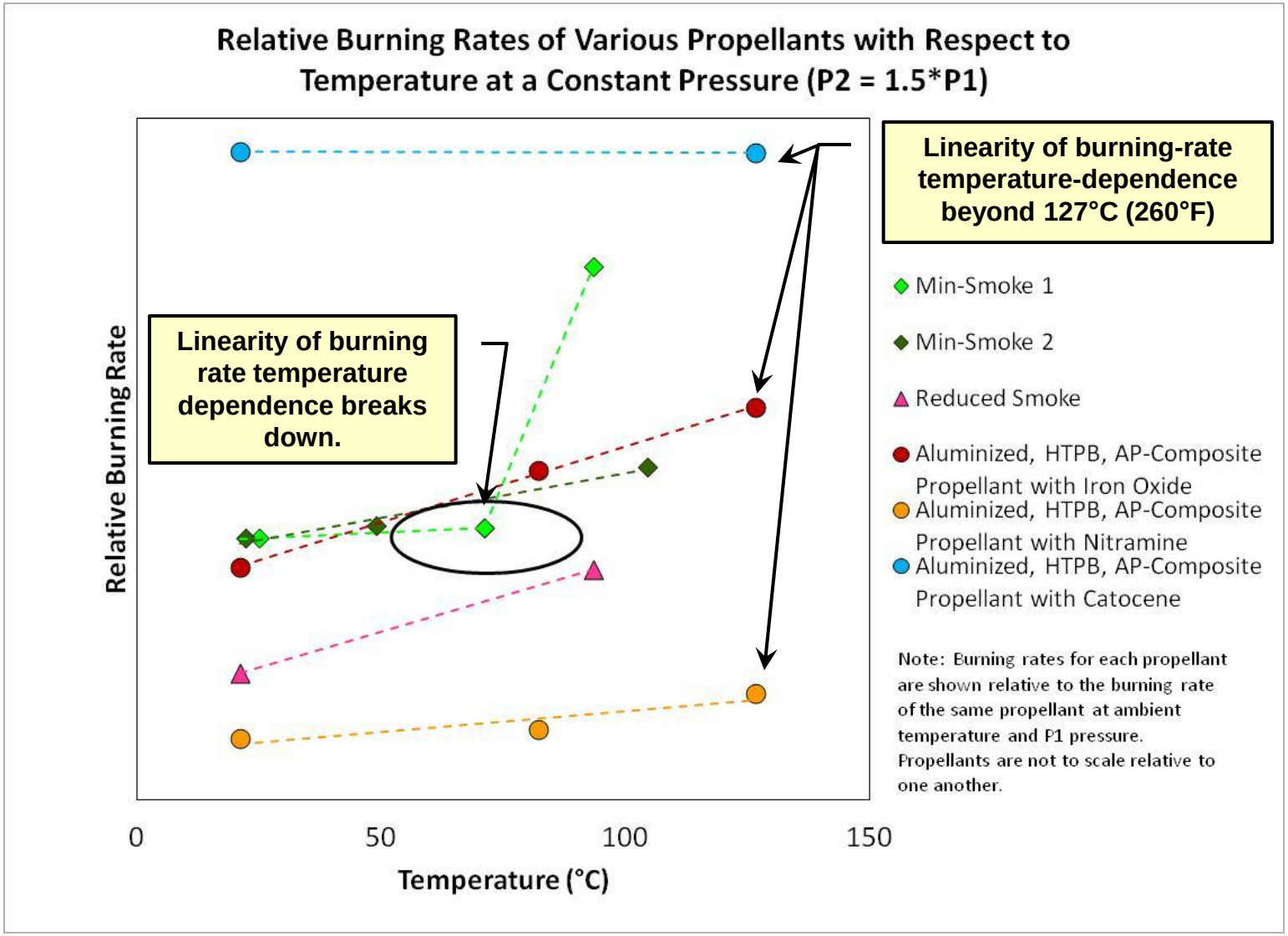
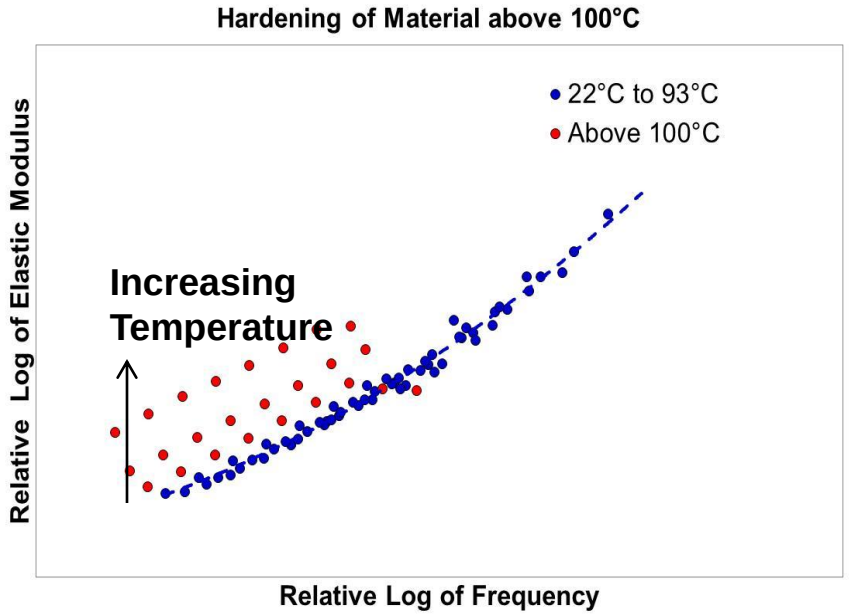


Why Venting?

- **Pressurization is controlled:**
  - **Burning surface area**
    - **dependent on grain design and surface regression of the propellant**
  - **Ballistic properties of the propellant**
    - **dependent on operating pressure & temperature**
  - **Venting**
- **Controlled venting can prevent the feedback loop than ensues from high-temperature propellant**
  - **Unvented, higher temperatures cause higher burning rates, which cause higher pressures, which cause exponentially higher burning rates.**
- **Controlled venting can cause the system to operate at lower pressures and prevent the system from becoming propulsive.**

What about the Mechanical Properties above 100°C?

- **Assessing structural integrity is not as simple as loading and temperature.**
- **Constitutive models are required which take into account additional cross-linking of polymers which may occur at IM mitigation temperatures.**



Conclusions and Recommendations

- **The system must be considered when seeking an IM solution.**
- **Researchers must always assess whether the right test is being performed for the information desired.**
  - **Cookoff reaction violence may not scale.**
- **If we understand the properties of the materials involved above the normal operation temperatures, we can design solutions which satisfy system safety requirements and reduce the consequence of an IM event.**