* Background reading
  + [Material Thermal Degradation Under Reentry Aerodynamic Heating (2014) | Deependran Balakrishnan | 17 Citations](https://typeset.io/papers/material-thermal-degradation-under-reentry-aerodynamic-1ug5gzyv1k)
  + [SDC8-paper210.pdf](https://conference.sdo.esoc.esa.int/proceedings/sdc8/paper/210/SDC8-paper210.pdf)
  + [Re-entry Heat Shields: Materials and Design for Spacecraft Protection - Space Voyage Ventures](https://spacevoyageventures.com/re-entry-heat-shields-materials-and-design/)
  + [Webinar 01312023-Final.pdf](https://ntrs.nasa.gov/api/citations/20230001416/downloads/Webinar%2001312023-Final.pdf)
  + [Thermite-for-Demise: Preliminary on-Ground Heat Transfer Experimental Testing | AIAA SciTech Forum](https://arc.aiaa.org/doi/10.2514/6.2023-1778)
* List of potential measuring instruments for material degradation
  + Temperature and heat
    - Thermocouple
      * Voltage across the double-wire depends on temperature
        + [What is a thermocouple and how does it work?](https://www.omega.co.uk/prodinfo/thermocouples.html)
      * Uses the Seebeck Effect
        + [The Seebeck Effect: How Temperature Differences Generate Electricity | Electrical4U](https://www.electrical4u.com/seebeck-effect-and-seebeck-coefficient/)
      * Used in [Advancing spacecraft demisability through a novel composite bolt joint system: a step toward sustainable and safe space environments | CEAS Space Journal](https://link.springer.com/article/10.1007/s12567-023-00531-x)
    - Infrared camera
    - Heat Flux sensors
      * Measure heat transfer through a surface
      * [Heat flux sensors: the latest technologies](https://www.hukseflux.com/library/heat-flux-sensors-latest-technologies)
  + Strain
    - Strain gauge
      * Measures strain via extension of wires and change of resistance
      * [Strain Gauge: Working Principle & Diagram | Electrical4U](https://www.electrical4u.com/strain-gauge/)
    - Optical fibre sensors
      * Can measure strain amongst other variables
      * Fiber Bragg Grating detects shifting in Bragg wavelength/ temperature from change in shift of reflected wavelength
        + [Microsoft Word - 01\_Allil\_final.docx](https://cdn.intechopen.com/pdfs/44684/intech-a_guide_to_fiber_bragg_grating_sensors.pdf)
      * Sources:
        + [Optical Fiber Sensors: Working Principle, Applications, and Limitations - Elsherif - 2022 - Advanced Photonics Research - Wiley Online Library](https://onlinelibrary.wiley.com/doi/full/10.1002/adpr.202100371?msockid=0a55f8df2a8e6e1a0919edfb2bac6f38)
        + [Functional Optical Fiber Sensors Detecting Imperceptible Physical/Chemical Changes for Smart Batteries | Nano-Micro Letters](https://link.springer.com/article/10.1007/s40820-024-01374-9)
        + [Microsoft Word - 01\_Allil\_final.docx](https://cdn.intechopen.com/pdfs/44684/intech-a_guide_to_fiber_bragg_grating_sensors.pdf)
  + Vibrations and sound
    - Vibration sensors
      * Layers polarised in opposite directions move when vibrated, causing a current
      * Product example: [RS PRO Vibration Sensor, 100 Hz, -15°C → +55°C | RS](https://uk.rs-online.com/web/p/vibration-sensors/0285784)
      * Sources:
        + [Efficient Structural Damage Detection with Minimal Input Data: Leveraging Fewer Sensors and Addressing Model Uncertainties](https://www.mdpi.com/2227-7390/12/21/3362)
    - Acoustic emission sensors
      * Locates cracks and defects in materials by measuring acoustic waves released by high pressures or temperatures
      * Sources:
        + [What Is Acoustic Emission Testing? A Definitive Guide - TWI](https://www.twi-global.com/technical-knowledge/faqs/acoustic-emission-testing)
        + [Acoustic emission testing (AET) - A Complete Guide](https://www.aendt.com/blog/acoustic-emission-testing.html)
  + Pressure and stress
    - Pressure sensors
      * Measure fluid pressure by the deformation of a diaphragm- like membrane material’s strain
      * Sources:
        + [Advances in high-performance MEMS pressure sensors: design, fabrication, and packaging | Microsystems & Nanoengineering](https://www.nature.com/articles/s41378-023-00620-1)
        + [What Is A Pressure Sensor? Pressure Sensors Working Principle - Piping Technology System](https://pipingtechs.com/what-is-a-pressure-sensor/)
    - Piezoelectric sensors
      * Measure mechanical strain by using crystal that outputs corresponding voltage
        + [What is Piezoelectric Sensor - Construction, Working & Applications](https://www.electricaltechnology.org/2020/05/piezoelectric-sensor.html)
  + Recession sensors
    - Measure erosion of a material in extreme environments, such as that of the Thermal Protection Systems (TPS) of spacecraft re-entry
    - Capacitive recession sensors measure how capacitance changes as dielectric is worn
    - ARAD/HEAT sensors developed by NASA
      * [Microsoft Word Viewer - 60518.docx](https://ntrs.nasa.gov/api/citations/20140005545/downloads/20140005545.pdf)
      * [(1) Current developments in future planetary probe sensors for TPS | Ed Martinez - Academia.edu](https://www.academia.edu/6829841/Current_developments_in_future_planetary_probe_sensors_for_TPS)
      * [(1) MIRKA2: Small Re-Entry Demonstrator for Advanced Miniaturized Sensors | Georg Herdrich - Academia.edu](https://www.academia.edu/63307995/MIRKA2_Small_Re_Entry_Demonstrator_for_Advanced_Miniaturized_Sensors?auto=download)
    - ReWiG sensor developed by ESA
      * Measures resistance change of grid of wires as it is damaged over time
      * [ReWiG: A Resistive Wire Grid TPS recession sensor | Nebula Public Library](https://nebula.esa.int/content/rewig-resistive-wire-grid-tps-recession-sensor)
    - Sources:
      * [IEEE Aero-Conference Big Sky-10192022.pdf](https://ntrs.nasa.gov/api/citations/20220015212/downloads/IEEE%20Aero-Conference%20Big%20Sky-10192022.pdf)
      * [Webinar 01312023-Final.pdf](https://ntrs.nasa.gov/api/citations/20230001416/downloads/Webinar%2001312023-Final.pdf)
      * [Microsoft PowerPoint - 6thAblationWorkshop\_Winter\_seeding](https://ntrs.nasa.gov/api/citations/20190001960/downloads/20190001960.pdf)
      * [Remote Recession Sensing of Ablative Heat Shield Materials - NASA Technical Reports Server (NTRS)](https://ntrs.nasa.gov/citations/20140011534)
      * [251419.pdf](https://eprints.gla.ac.uk/251419/1/251419.pdf)
        + Details number of recession sensor techniques