National Aeronautics and Space Administration

Debris Removal: An Opportunity for Cooperative Research?

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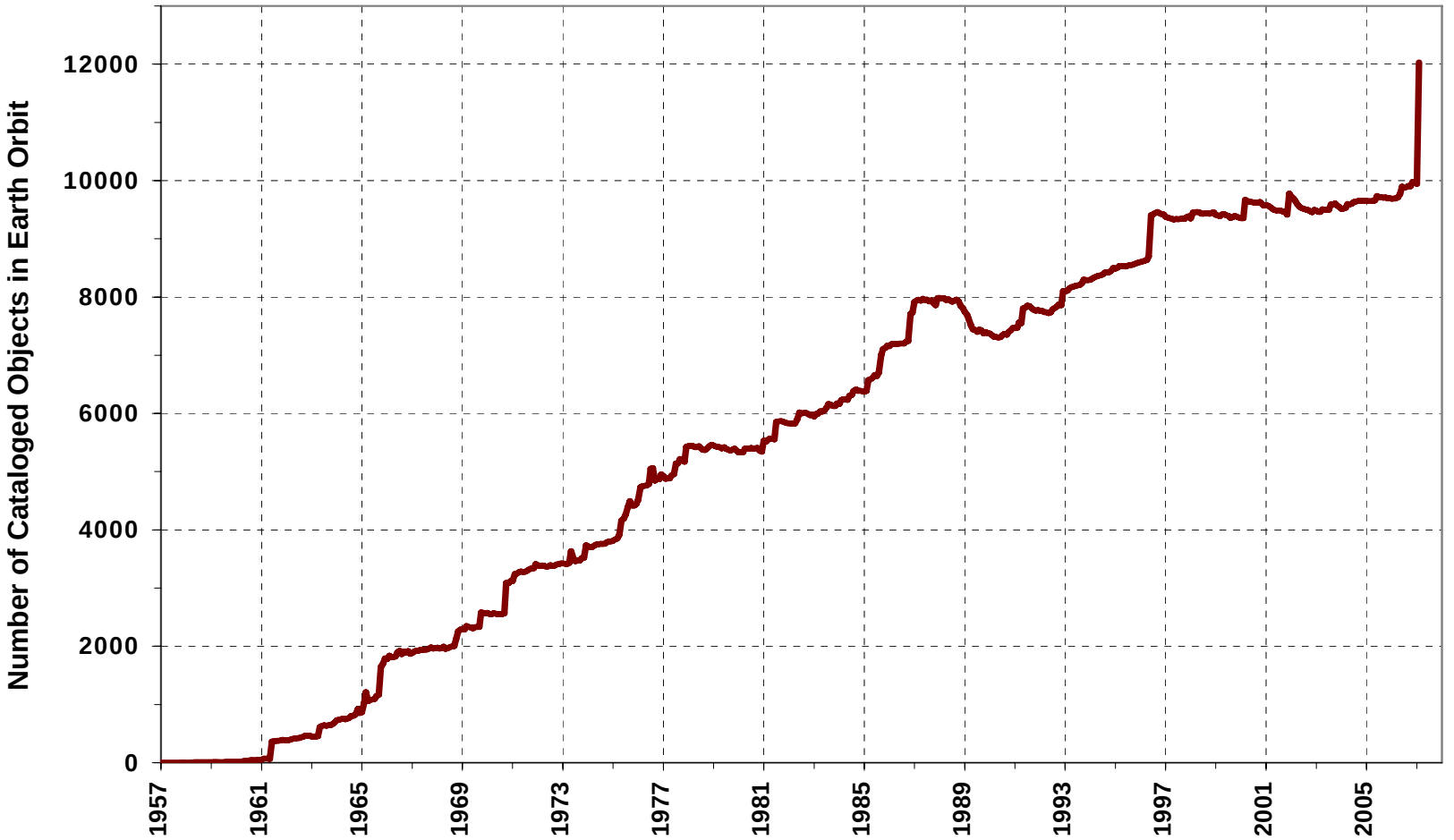
Space Situational Awareness Conference
25-26 October 2007

Outline

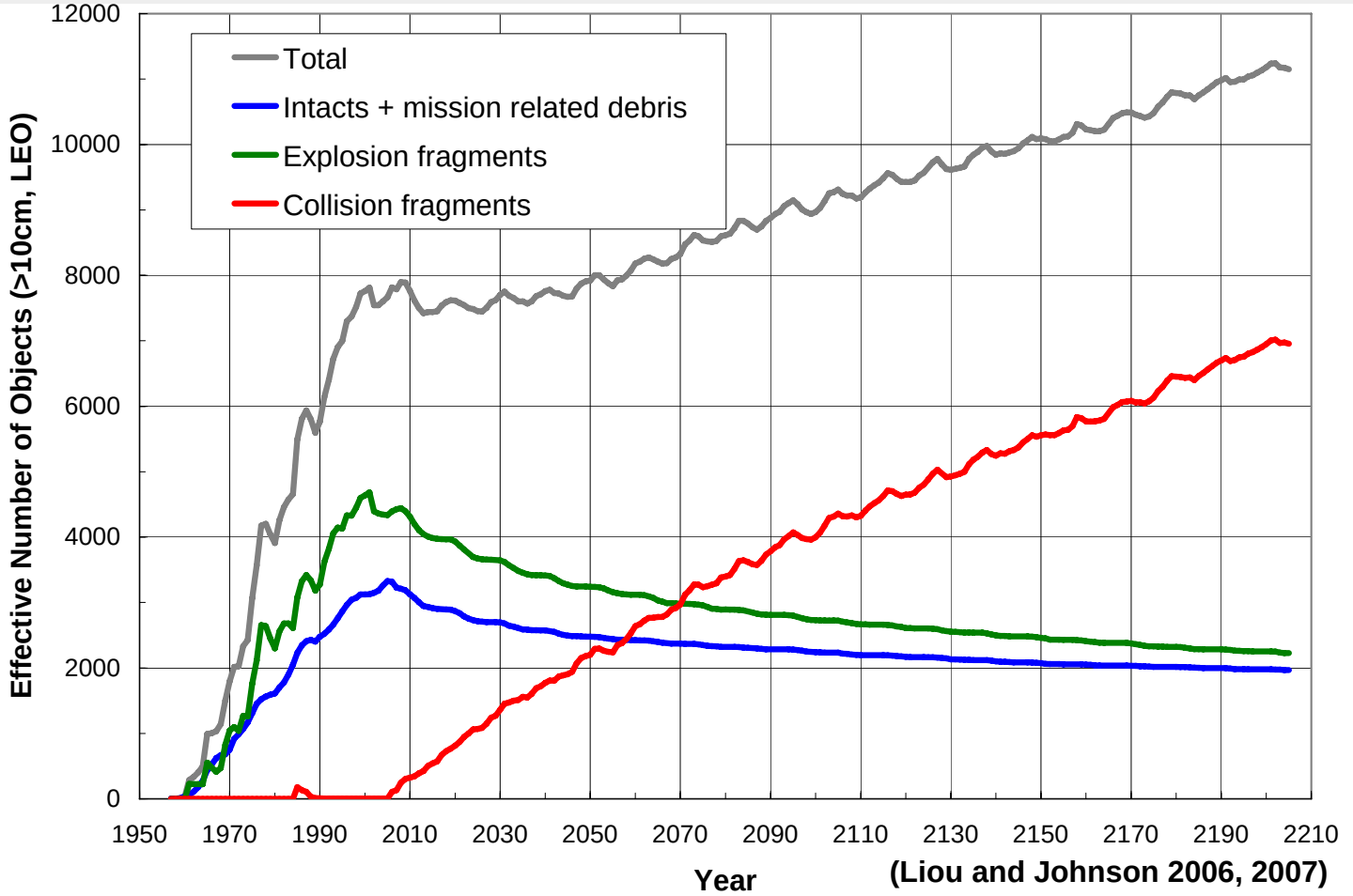
- **Incentive for debris removal**
- **Potential benefits of debris removal**
- **Debris removal categories and concepts**
- **Technical, Economic, and Legal Challenges**

Evolution of Satellite Population

- **The population of large objects in Earth orbit continues to grow.**



Projected Growth of LEO Populations
(no new launches beyond 1/1/2006)

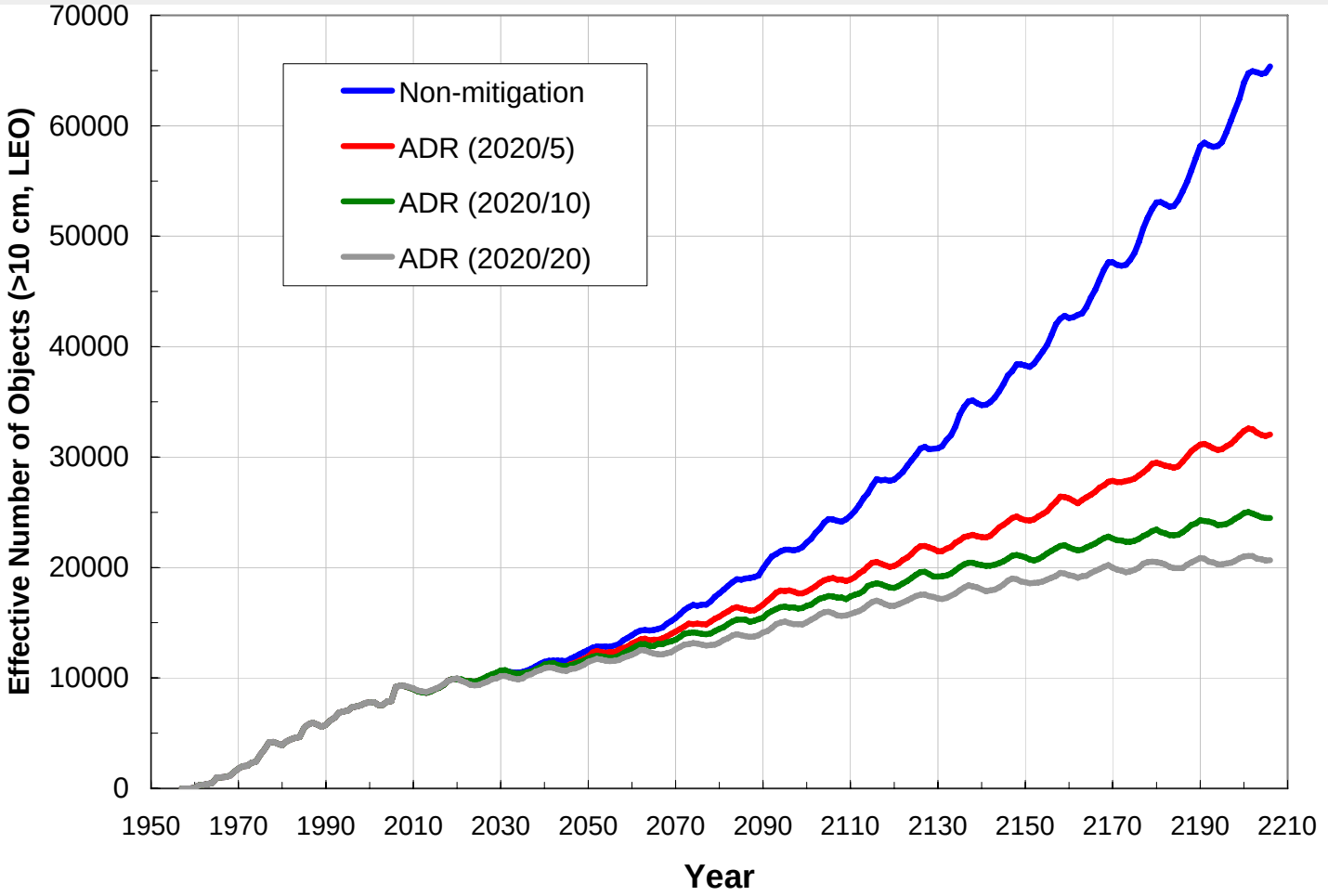


- **Collision fragments replace other decaying debris through the next 50 years, keeping the total population approximately constant**
- **Beyond 2055, the rate of decaying debris decreases, leading to a net increase in the overall satellite population due to collisions**

What is the Future?

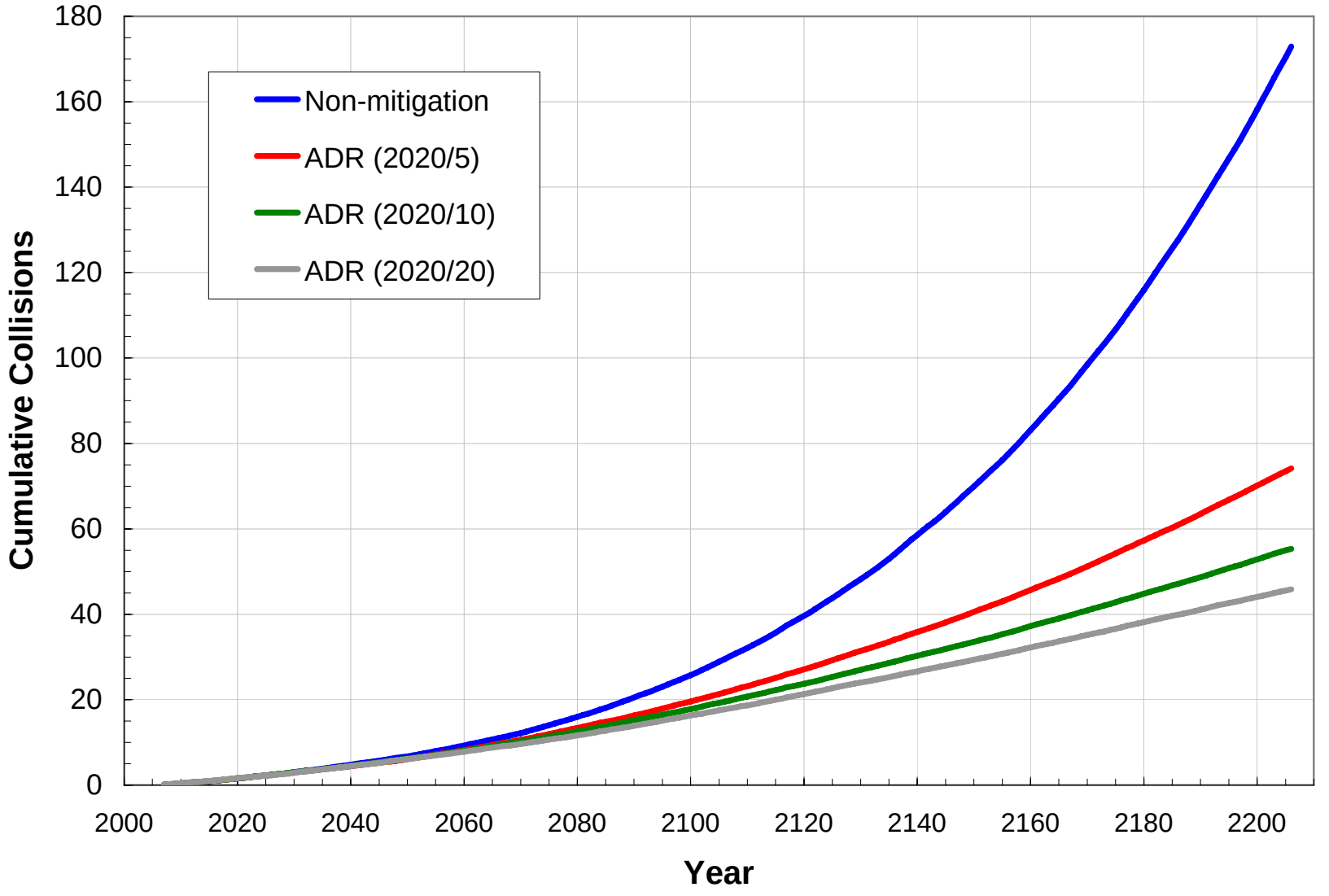
- **In reality, the situation will be worse than the “no new launches” scenario since**
  - satellites continue to be launched into space
  - unexpected major breakups continue to occur
- **Postmission disposal (such as a 25-year decay rule) will help, but will be insufficient to prevent the self-generating phenomenon from happening.**
- **To better limit the growth of the future debris population, active removal of existing objects from orbit should be considered.**

Potential Benefits of Active Debris Removal (ADR)

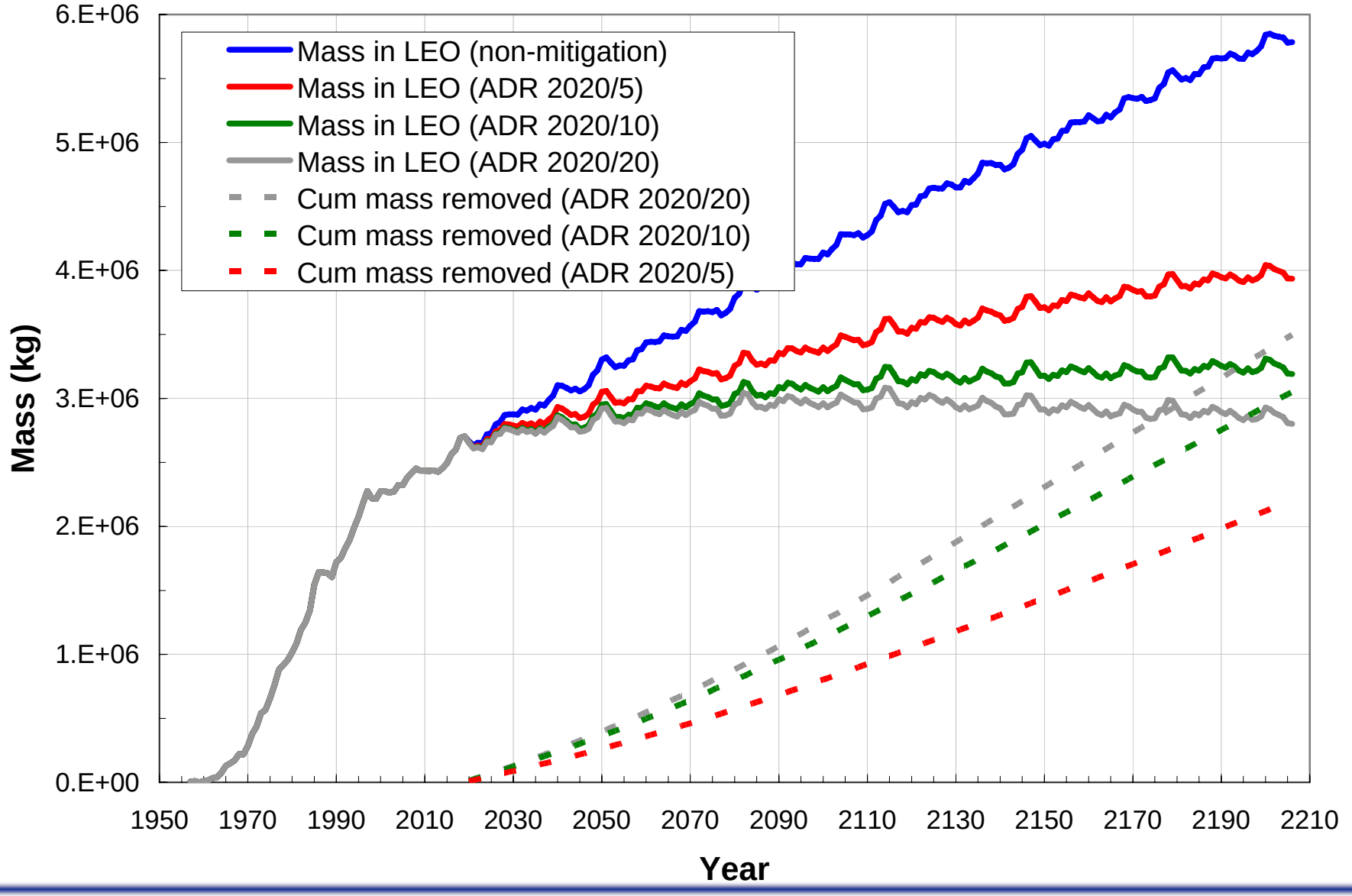


- **2020/5: Five objects removed annually beginning in 2020**
- **2020/10: Ten objects removed annually beginning in 2020**
- **2020/20: Twenty objects removed annually beginning in 2020**

Debris Removal Curtails Future Collisions



Mass in Orbit and Mass Removed



Debris Removal Concept Principles

- **Must be technically feasible in the near-term.**
- **Must be economically viable.**
  - Affordable
  - Acceptable cost-benefit ratio
- **Must result in a meaningful improvement of the current or future near-Earth space environment.**

IAA Study Group

- **At 2006 International Astronautical Congress in Valencia, Spain, the International Academy of Astronautics (IAA) formed a study group on "Space Debris Environment Remediation".**

- **The primary goal of the study is to "examine the feasibility and effectiveness of space object removal to control the space debris environment".**

- **Intermediate goals include:**

  - Identification and critical analysis of different techniques for removing mass from orbit

  - Investigation of legal aspects of the implementation of such techniques

- **Target final report date: mid 2009**

Debris Removal Categories

- **Debris removal concepts are often categorized by**
  - The size of the debris to be removed: typically < or > 10 cm (statistical or designated removal)
  - The altitude regime of removal: LEO, MEO, or GEO
  - The basing of the removal device: ground-based, air-based, or space-based
- **Removal of small debris normally affects the near-term environment by reducing collision probabilities for existing space systems, e.g., cleansing human space flight altitude regimes.**
- **Removal of large debris influences the mid-term and far-term environments by reducing the number of debris-generating collisions.**

Sample of Debris Removal Concepts

Debris Removal Technique	Altitude Regime	Debris Size Regime
Ground-based Laser/Directed Energy	LEO	< 10 cm
Airborne Laser/Directed Energy	LEO	< 10 cm
Space-based Laser/Directed Energy	LEO, MEO, GEO	< 10 cm
Space-based Magnetic Field Generator	LEO	< 10 cm
Drag Augmentation Device	LEO	> 10 cm
Solar Sail	LEO, MEO, GEO	> 1 m
Magnetic Sail	LEO, MEO, GEO	> 1m
Momentum Tethers	LEO, GEO	> 10 cm
Electrodynamic Tethers	LEO	> 10 cm
Capture/Orbital Transfer Vehicle	LEO, MEO, GEO	> 1 m
Attachable Deorbit/Reorbit Module	LEO, MEO, GEO	> 1 m
Sweeping/Retarding Surface (balloon, film, foam ball, etc.)	LEO	< 10 cm

Selected Current Challenges

- **Most debris removal concepts rely on one or more elements of unproven technology (physical or operational).**
- **Deployment and operations costs can be very high, particularly for space-based systems.**
- **Source of funding (government or commercial) is unclear.**
- **Existing treaties and conventions might inhibit the removal of large debris.**
  - Owner's consent
  - Liability issues
- **Uncontrolled reentry of large debris poses additional risks of human casualty and property damage.**

Summary

- **Space debris mitigation practices will be insufficient to prevent the continued growth of the Earth satellite population.**
- **Removal of orbital debris can improve the reliability of present and future space systems.**
- **The challenges of developing an effective, affordable debris removal capability are considerable.**
- **The time is right for a new look at space remediation concepts.**
  - In concert with or following the current IAA study
- **An international approach to the remediation of the near-Earth space environment will likely be required.**