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# Gene Drives on the Horizon: Advancing Science, Navigating Uncertainty, and Aligning Research with Public Values

Public Release Event  
June 8, 2016



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**COMMITTEE ON GENE DRIVE RESEARCH IN NON-HUMAN ORGANISMS:  
RECOMMENDATIONS FOR RESPONSIBLE CONDUCT**

# Committee on Gene Drive Research (by expertise)

## Biosafety and Biosecurity

**Stephen Higgs**, Kansas State University

## Developmental Biology

**Lisa A. Taneyhill**, University of Maryland

## Ecological Risk Assessment

**Wayne Landis**, Western Washington University

## Entomology and Vector-Borne Diseases

**Nicole L. Achee**, University of Notre Dame  
**Lynn Riddiford**, Howard Hughes Medical Institute

## Ethics and Scientific Integrity in Research

**Elizabeth Heitman**, *Co-Chair*, Vanderbilt University Medical Center  
**Gregory E. Kaebnick**, The Hastings Center

## Plant Biology and Ecology

**Vicki Chandler**, Minerva Schools at Keck Graduate Institute

**Brandon S. Gaut**, University of California, Irvine

## Population Ecology

**James P. Collins**, *Co-Chair*, Arizona State University  
**Joseph Travis**, Florida State University  
**Paul E. Turner**, Yale University

## Public Interfaces with Controversial Science

**Jason A. Delborne**, North Carolina State University

## Science and Technology Policy and Law

**Ann Kingiri**, African Centre for Technology Studies  
**Joyce Tait**, University of Edinburgh  
**David E. Winickoff**, University of California, Berkeley

# The Committee's Process

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GENE DRIVE RESEARCH IN  
NON-HUMAN ORGANISMS:  
Recommendations for Responsible Conduct

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## Gene Drive Research in Non-Human Organisms: Recommendations for Responsible Conduct

Welcome to the National Academies of Sciences, Engineering, and Medicine study examining a range of questions and opinions about the science, oversight, governance, and ethics of gene-drive research. Gene drives, a type of gene editing, spread gene modifications throughout a population of organisms intentionally. This study is intended to provide an independent, objective examination of what has been learned since the development of gene drives based on current evidence. The study is being conducted by a **committee of experts** and is expected to be released in 2016.

Follow on Twitter: [#GeneDriveStudy](#)

Send email to: [genedrivestudy@nas.edu](mailto:genedrivestudy@nas.edu)

Get updates

Provide input

Workshop: Science, Ethics, and Governance of Gene Drives

Webinar 1: Gene Drive Organisms

Webinar 2: Basic Research

Webinar 3: Risk Assessment

Webinar 4: Considerations for Commercial Applications

Webinar 5: Biosecurity

Webinar 6: Species Interactions

Webinar 7: US Regulations

Webinar 8: Containment Guidelines

Webinar 9: Field Research

Webinar 10: Environmental Perspectives

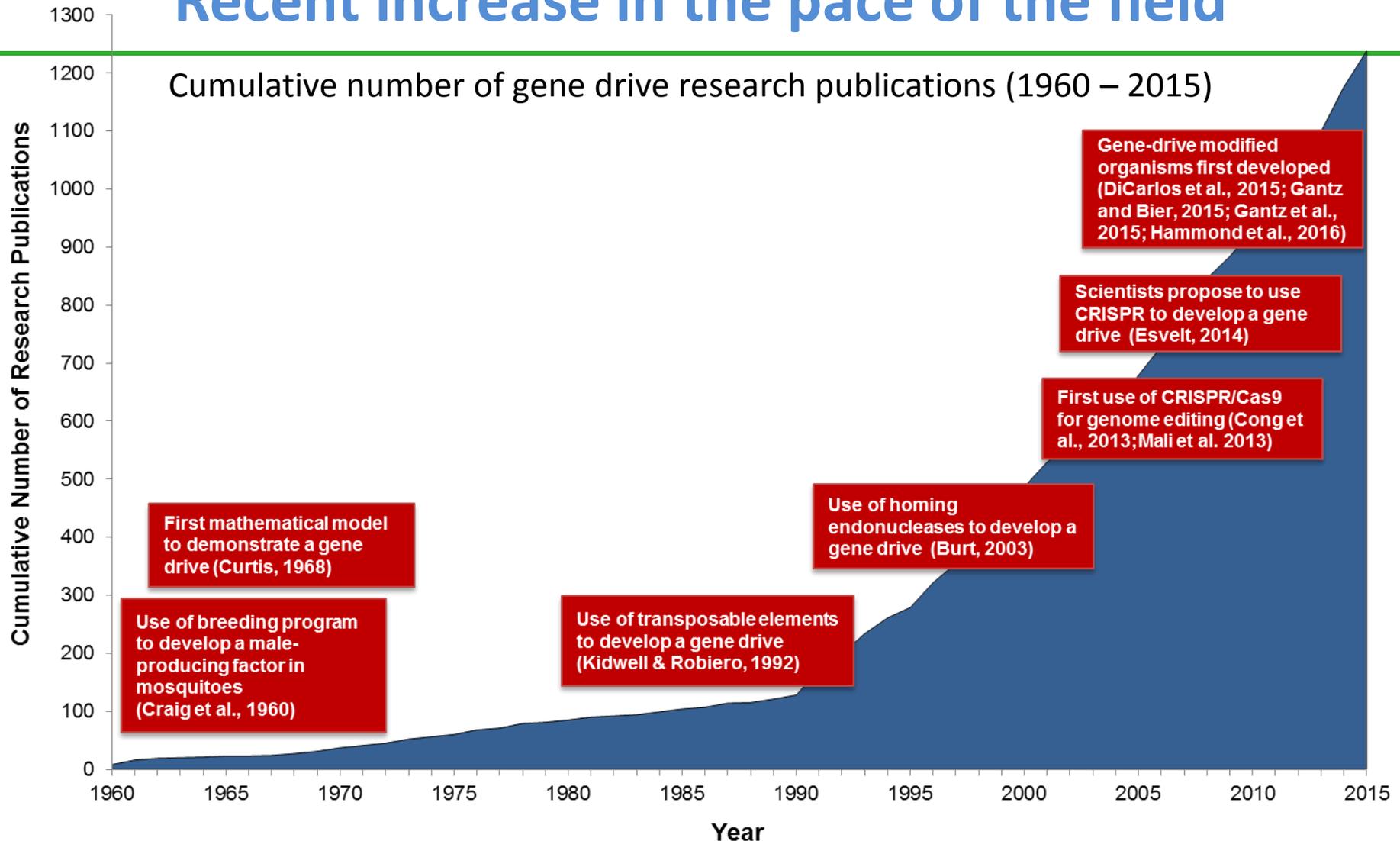
Webinar 11: International Capacity Building

- Consulted peer-reviewed literature
- Sought and included expert input through a public workshop and webinar series
- Sought and included public input

<http://nas-sites.org/gene-drives/>

# Motivations for the Study

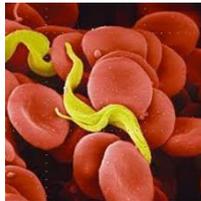
## Recent increase in the pace of the field



# Motivations for the Study

Many proposals for a wide variety of challenging issues

## Public Health



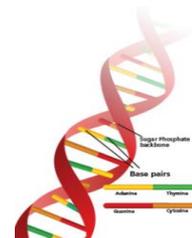
## Conservation



## Agriculture



## Basic Research



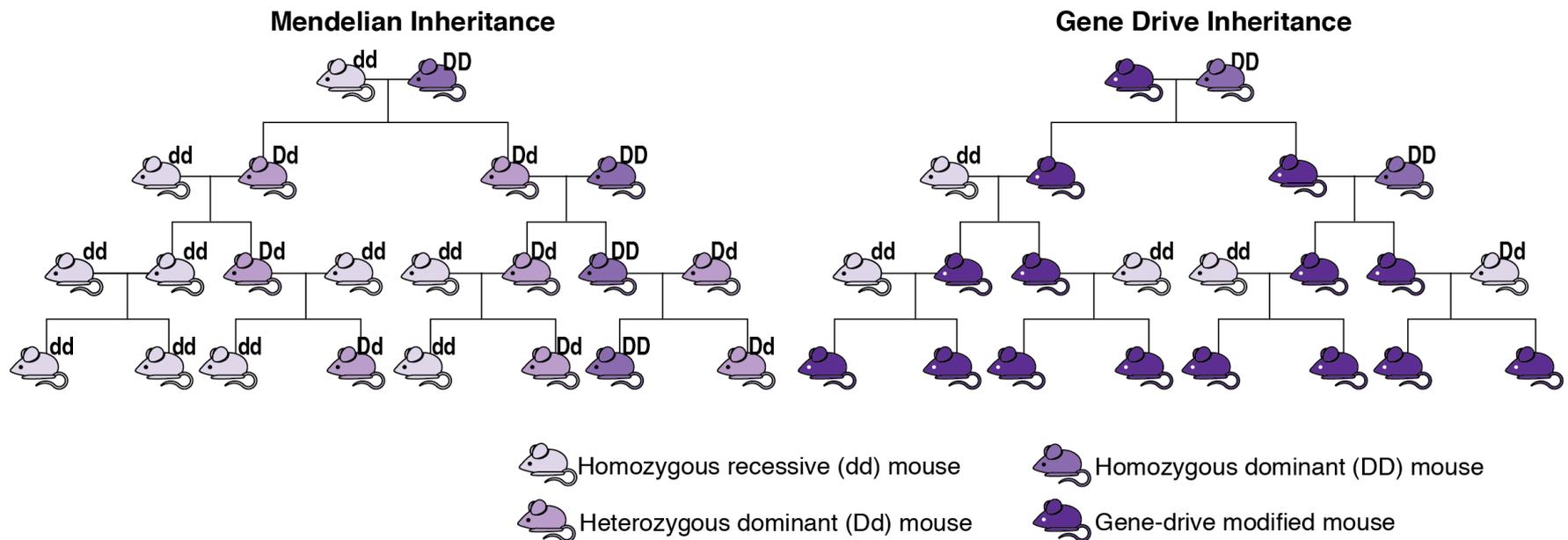
# Motivations for the Study

## Many questions about science, ethics, and governance

- Could gene drives have unintended consequences for public health and the environment?
- Do we know enough to consider releasing gene-drive modified organisms into the environment?
- *Should* a gene drive be used to suppress or eliminate a pest species?
- How do we decide where gene-drive modified organisms could be released? What should be governments' role?

# What are gene drives?

Gene drives are systems of biased inheritance in which the ability of a genetic element to pass from a parent organism to its offspring through sexual reproduction is enhanced.



# Basic Facts About Gene Drives

- Occur in nature in many species
- Work through various mechanisms
- Earliest proposals to develop them came in the mid-20<sup>th</sup> century, but until now the technology was not available to design a gene drive to spread a specific trait throughout a population

# Key Features and Potential Uses of Gene Drives

- Defining features:
  - Spread and persistence
  - Potential to cause irreversible ecological change
- Two potential uses:
  - Population suppression: Decrease numbers
  - Population replacement: Change genetic characteristic(s)

# Criteria for Choosing a Species to Develop a Gene Drive

- Sexual reproduction
- Short generation time
- Stability of the driving genetic elements
- Population structure that facilitates the spread of the gene drive

# Responsible Science to Develop Gene Drive Technologies



A responsible science approach calls for continuous evaluation and assessment of the social, environmental, regulatory, and ethical considerations of gene drives.

Researchers, institutions, funders, and professional societies have a responsibility to provide education and training on responsible science for gene drive research.

# Values Are Important at Every Step



Questions about responsible science, from why and how research should be conducted to whether, when, and where a gene-drive modified organism could be released into the environment rest on values at every step.

Widely-shared commitments to protecting human welfare and the environment call for public policy guidelines that may constrain research on gene drives or the release of gene-drive modified organisms. Integrating precautionary measures into the research process can help to balance potentially conflicting commitments.

# State of the Science



There is insufficient evidence available at this time to support the release of gene-drive modified organisms into the environment. However, the potential benefits of gene drives for basic and applied research are significant and justify proceeding with laboratory research and highly-controlled field trials.

There are considerable gaps in knowledge, particularly in regard to ecological and evolutionary considerations for the organism and its ecosystem that in turn affect risk assessments, public engagement, and governance.

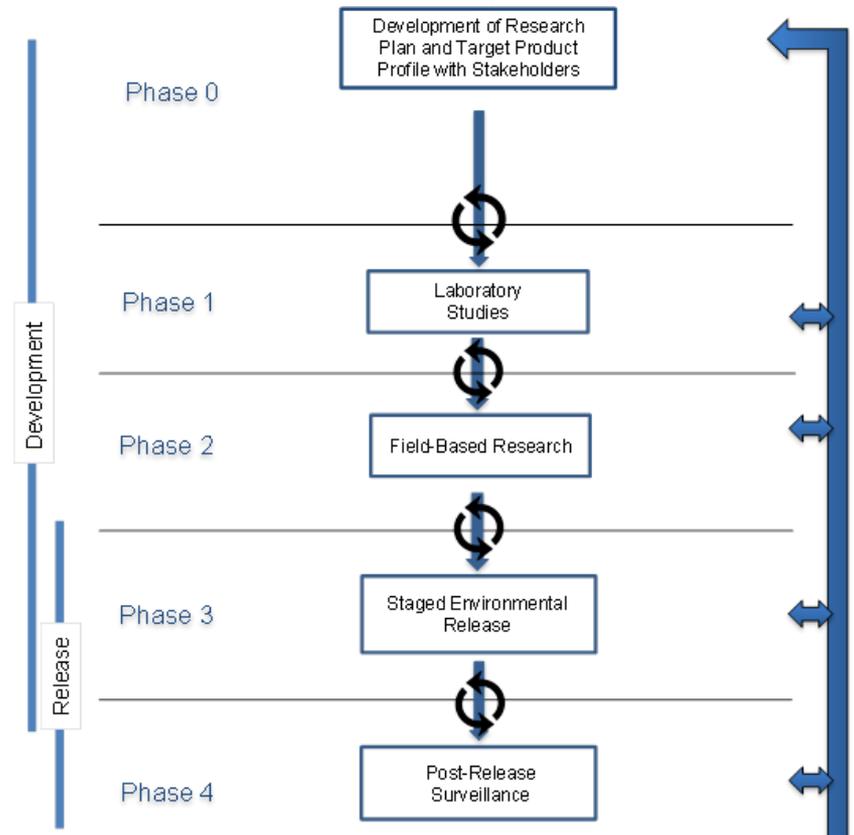
**Recommendation:** Funders of gene drive research should coordinate, and if feasible collaborate, to reduce the gaps in knowledge.

# Phased Testing: A precautionary approach



Because gene drives are intended to spread and persist in the environment, it is crucial to:

- Understand the target organism, its role in the environment, and potential for unintended consequences such as off and non-target effects
- Develop confinement and containment strategies to minimize unintended persistence or release
- Develop mechanisms to detect and monitor gene-drive modified organisms



# Phased Testing: Safety considerations



**Confinement** is the use of ecological conditions or biological methods to prevent unintended or uncontrolled *persistence* of an organism in the environment (e.g., climatic isolation).

**Containment** is the use of human-made or natural physical restrictions to prevent unintended or uncontrolled *release* of an organism into the environment (e.g., large cages, greenhouses, and aquaculture pens; geographic isolation).

## Recommendations:

- Whenever possible, researchers should include a gene drive that spreads a visible marker to distinguish modified organisms and facilitate research and monitoring.
- Researchers, regulators, and other decision-makers should not rely upon a “reversal” gene drive as the sole strategy for mitigating the effects of another gene drive.

# Phased Testing: Selecting sites for field tests



Criteria for site selection should include:

- Scientific and technical considerations (e.g., presence of the target species, methods for containment and confinement)
- Values of relevant publics
- Capabilities of local, regional, and national governance bodies
- Ability of researchers to engage with local communities

**Recommendation:** In site selection, preference should be given to locations in countries with the existing scientific capacity and governance frameworks to conduct and oversee the safe investigation of gene drives and development of gene-drive modified organisms.

# What Is Risk?

Technical definition: The *probability* of an effect on one or more specific endpoints due to a specific stressor or stressors.

In other words, how often a specific change or changes in the environment will affect something of value to society, such as human health, outdoor recreation, or the survival of an endangered species.

# From Environmental Assessment to Ecological Risk Assessment



It is possible to estimate risk due to gene drives using current methodologies.

Advantages of ecological risk assessment:

- Quantify the probability of specific outcomes
- Trace cause-and-effect pathways
- Identify sources of uncertainty
- Incorporate concerns of relevant publics
- Compare benefits and harms
- Compare alternative strategies
- Inform research and public policy decisions

Relevant U.S. guidelines and technical documents are not yet sufficient on their own to guide ecological risk assessment for gene drive technology.

# Public Engagement is needed in research, risk assessment, and governance



Public engagement cannot be an afterthought.

The outcomes of engagement may be as crucial as the scientific outcomes to decisions about whether to release a gene-drive modified organism into the environment.

**Recommendation:** Governing authorities, including research institutions, funders, and regulators, should develop and maintain clear policies and mechanisms for how public engagement will factor into research, ecological risk assessments, and public policy decisions about gene drives.

# Challenges to Governance of Gene Drive Research and Development (Part 1)



The governance of research begins with the personal responsibility of the investigator, is formalized in professional guidelines, and often extends to legally binding policies and enforceable regulations.

Existing mechanisms of governance may be inadequate to address potential immediate and long-term environmental and public health consequences because they:

- Do not consider gene drives' intentional spread and potential irreversible effects on ecosystems
- Lack clarity in their jurisdiction of oversight
- Provide insufficient structures for public engagement
- Do not address the potential for misuse
- Lack policies for collaborating with other countries with divergent systems of governance

# Challenges to Governance of Gene Drive Research and Development (Part 2)



The diversity of potential gene-drive modified organisms and contexts where they might be used reveals a number of overlaps and gaps in U.S. regulation.

- Is a gene drive inserted into a mouse a new animal drug (FDA), a rodenticide (EPA), or plant pest (USDA)?
- What are the responsibilities of U.S. agencies outside of the Coordinated Framework (e.g., U.S. Fish and Wildlife Service; Bureau of Land Management; National Park Service)?

**Recommendation:** The U.S. government should clarify the assignment of regulatory responsibilities for field releases of gene-drive modified organisms, including the roles of relevant agencies that are not currently included in the Coordinated Framework for the Regulation of Biotechnology.

# Challenges to Governance of Gene Drive Research and Development (Part 3)



Regulation of genetically modified organisms under the U.S. Coordinated Framework and the UN Convention on Biological Diversity (Cartagena and Nagoya Protocols) is predicated on containment. However, after release, a gene-drive modified organism is intended to spread.

Multinational approaches to governance would be required because a gene-drive modified organism knows no political boundaries.

**Recommendation:** Research institutions, regulators, and funders should revisit international regulatory frameworks, national laws, non-government policy, and professional codes of conduct on research to determine whether and how they may be applied to specific contexts of gene drive research.

# Acknowledgements

- Staff members
- Speakers and members of the public
- Report reviewers
- Committee members

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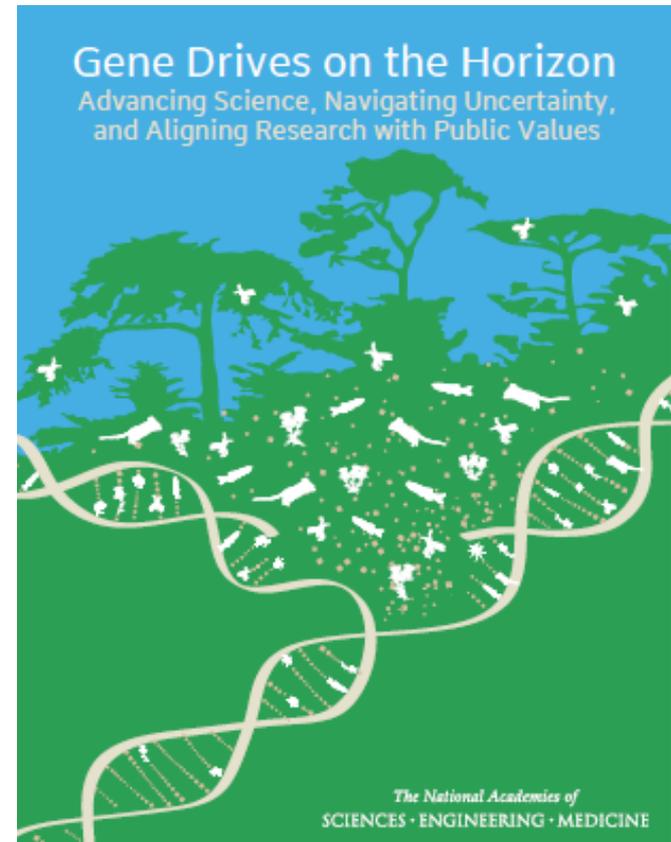
# Thank You!

Visit [nas-sites.org/gene-drives](https://nas-sites.org/gene-drives) to find:

- PDF of the report for free download
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- Briefing slides and archived webcast of public release



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