DARPA's Biological Technologies Office

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Office Director
Biological Technologies Office
Defense Advanced Research Projects Agency

Briefing prepared for Insect Allies proposers day

November 18, 2016

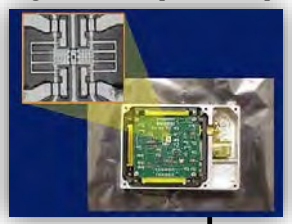
What is DARPA?

SATURN F1 Rocket Engine

Stealth Fighter

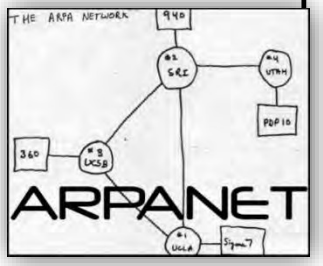
Speech Recognition

Microelectromechanical Systems (MEMS)



Brain-controlled Prosthetic Arm

1960 1970 1980 1990 2000 2010



ARPANET

Miniaturized GPS Receivers

Global Hawk

Autonomous Vehicle

Humanoid Robot

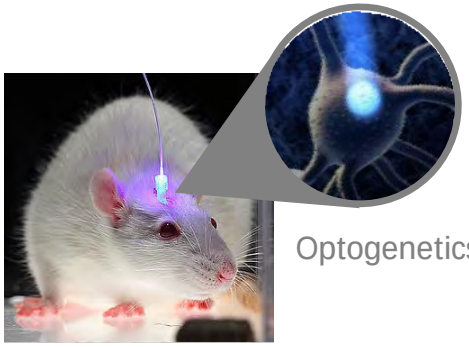
Biology presents new opportunities and challenges

Accessible gene editing tools

Emergence of infectious diseases

1995 2003 2004 2009 2014 2016

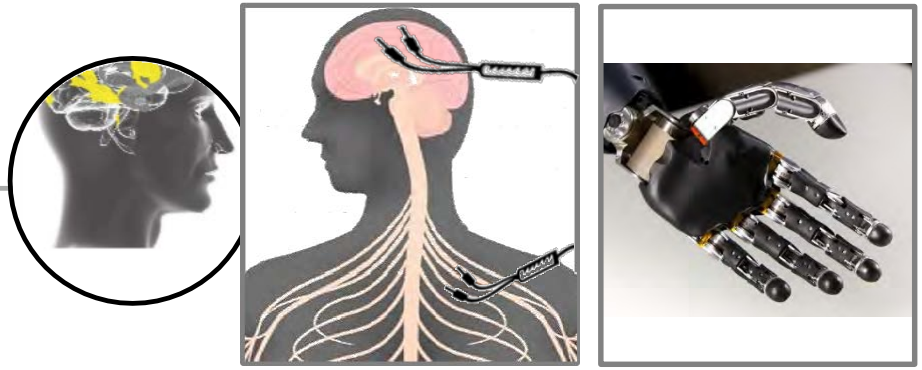
Direct interfaces to the brain and nervous system



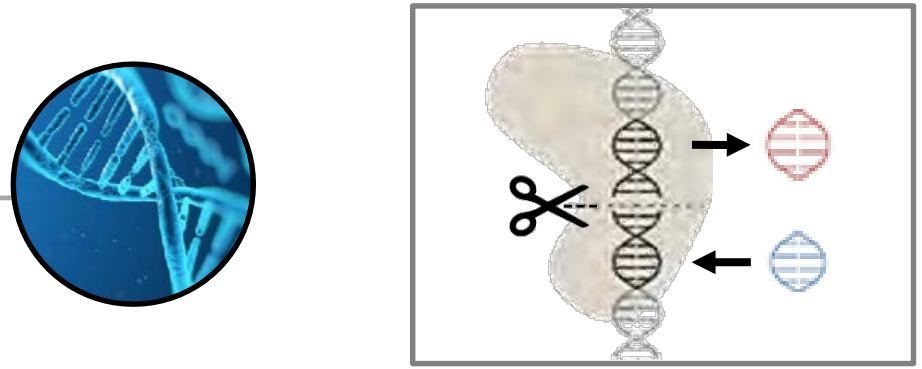
Optogenetics

Mission: Develop novel capabilities to support national security

NEUROTECHNOLOGY



GENE EDITING AND SYNTHETIC BIOLOGY



OUTPACING INFECTIOUS DISEASE

Who we serve

Control complex systems

Learn complex tasks and concepts

Manage extraordinary stress

Aid our wounded warriors

Neurotechnology: Revolutionizing Prosthetics

Motor Control

Sensory Feedback

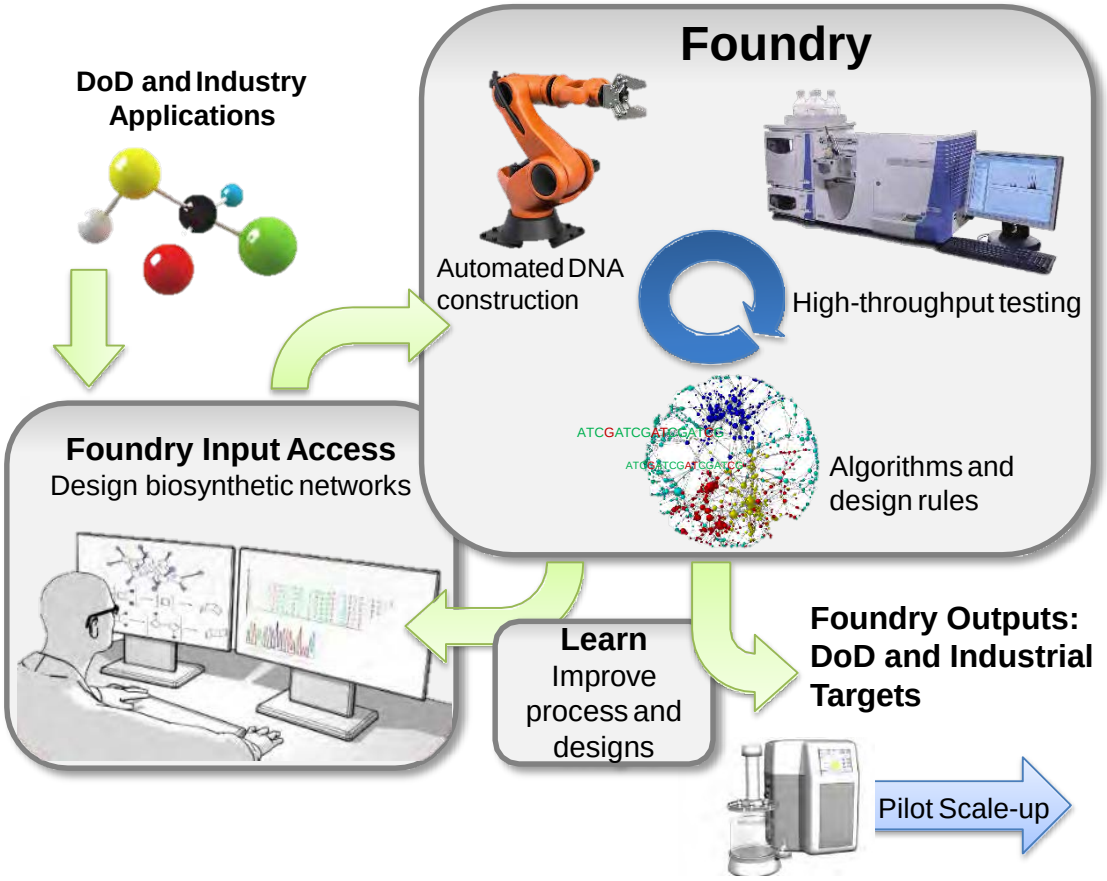
courtesy JHU-APL and University of Pittsburgh

Gene Editing and Synthetic Biology: Living Foundries

Goal: Create design rules and infrastructure for a rapid design and prototyping facility

Assemble and insert genes and regulatory sequences to form a biosynthetic pathway that produces the target molecule

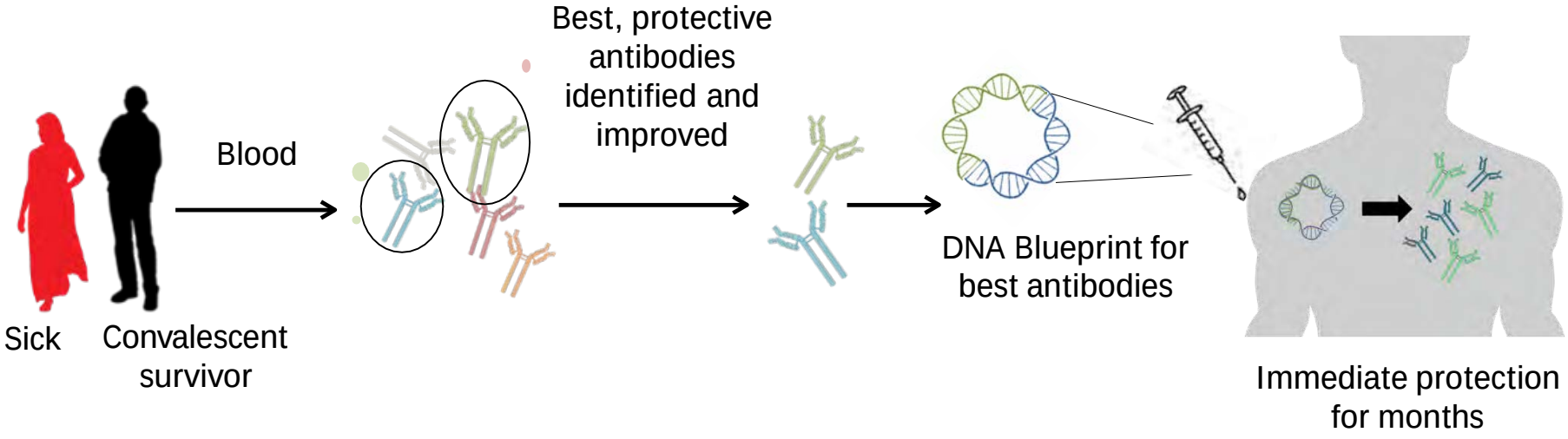
Cell metabolism



Genetic engineering in lower level organisms

Outpacing Infectious Disease: Antibodies for immediate immunity

Give the code and let the patient make the antibody

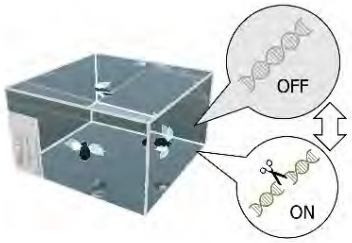


Transient genetic engineering in humans

Gene Editing and Synthetic Biology: Safe Genes

Goal: Create biological capabilities that enable the safe pursuit of advanced gene editing applications and protect against potential engineered genetic threats

Control of Gene Editing



Enable temporal, spatial, and reversible control of gene editors

Countermeasures and Prophylaxis

Inhibit unwanted gene editing activity

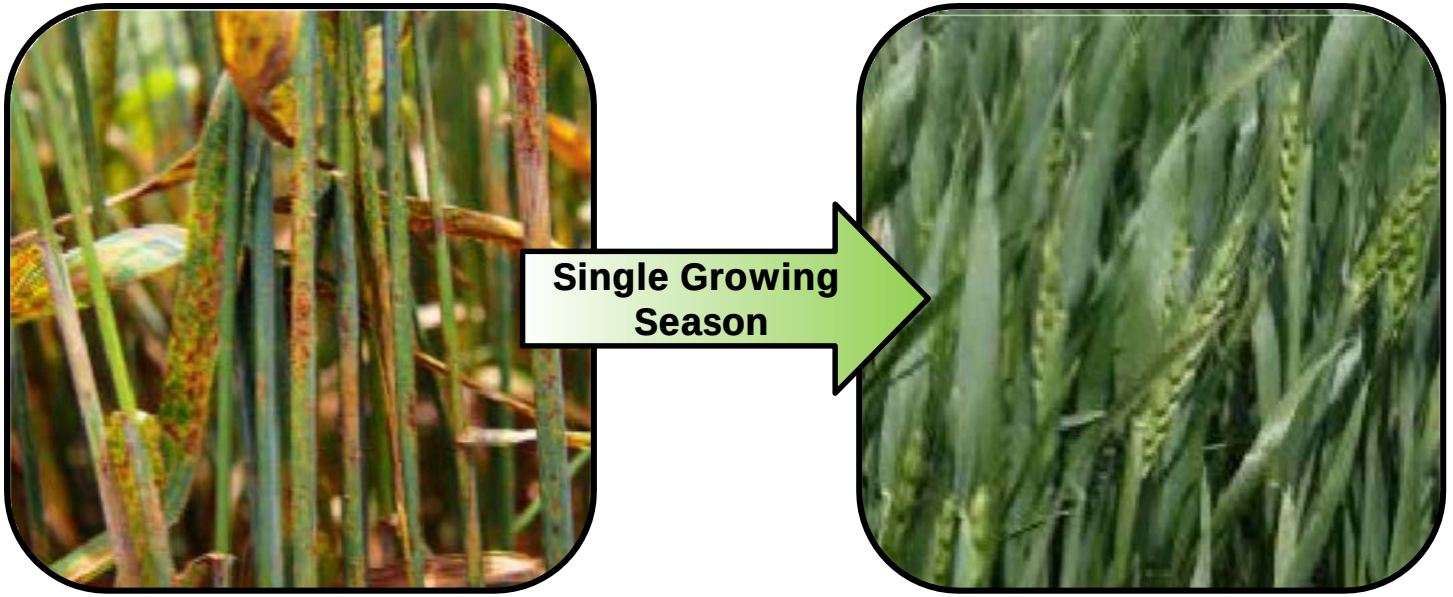
Genetic Remediation

Remove engineered genes from environments to return to baseline

Address the inherent risks that arise from the rapid democratization of gene editing tools

Plotting a course for the future of genetic engineering

Insect Allies



Apply lessons learned for gene editing and synthetic biology to enhance agricultural biosecurity and increase global food supply stability

www.darpa.mil

Blake Bextine, Ph.D.

Program Manager, Biological Technologies Office (BTO)

Proposers Day

Slides will be available at the registration website shortly

18 November 2016, Arlington, Virginia

Insect Allies Proposers Day Objectives

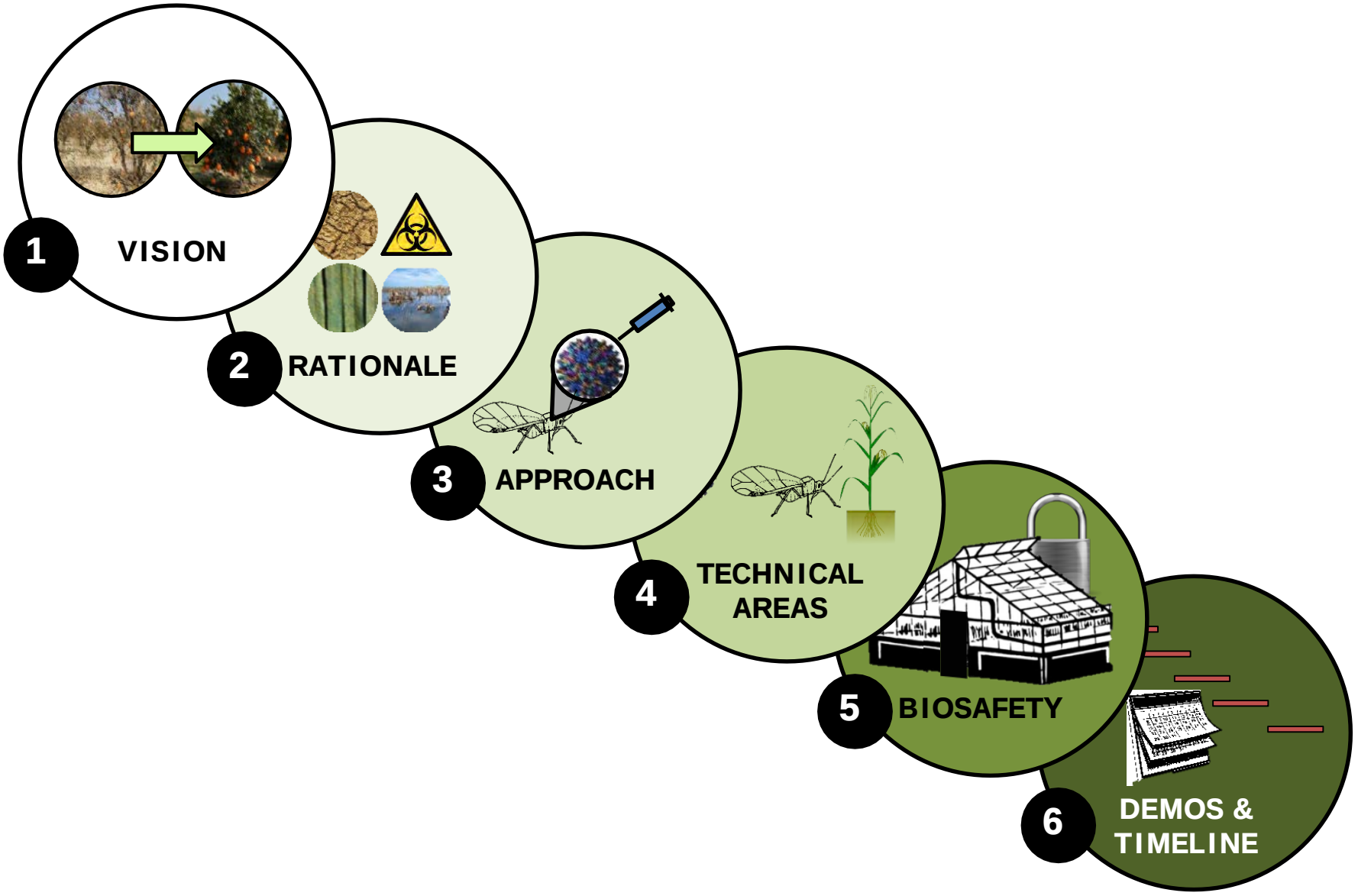
- To **introduce the science and technology community** (industry, academia, and government) to the Insect Allies program vision and goals;

- To explain the **logistics of DARPA contract awards** as well as the objectives of the Insect Allies program;

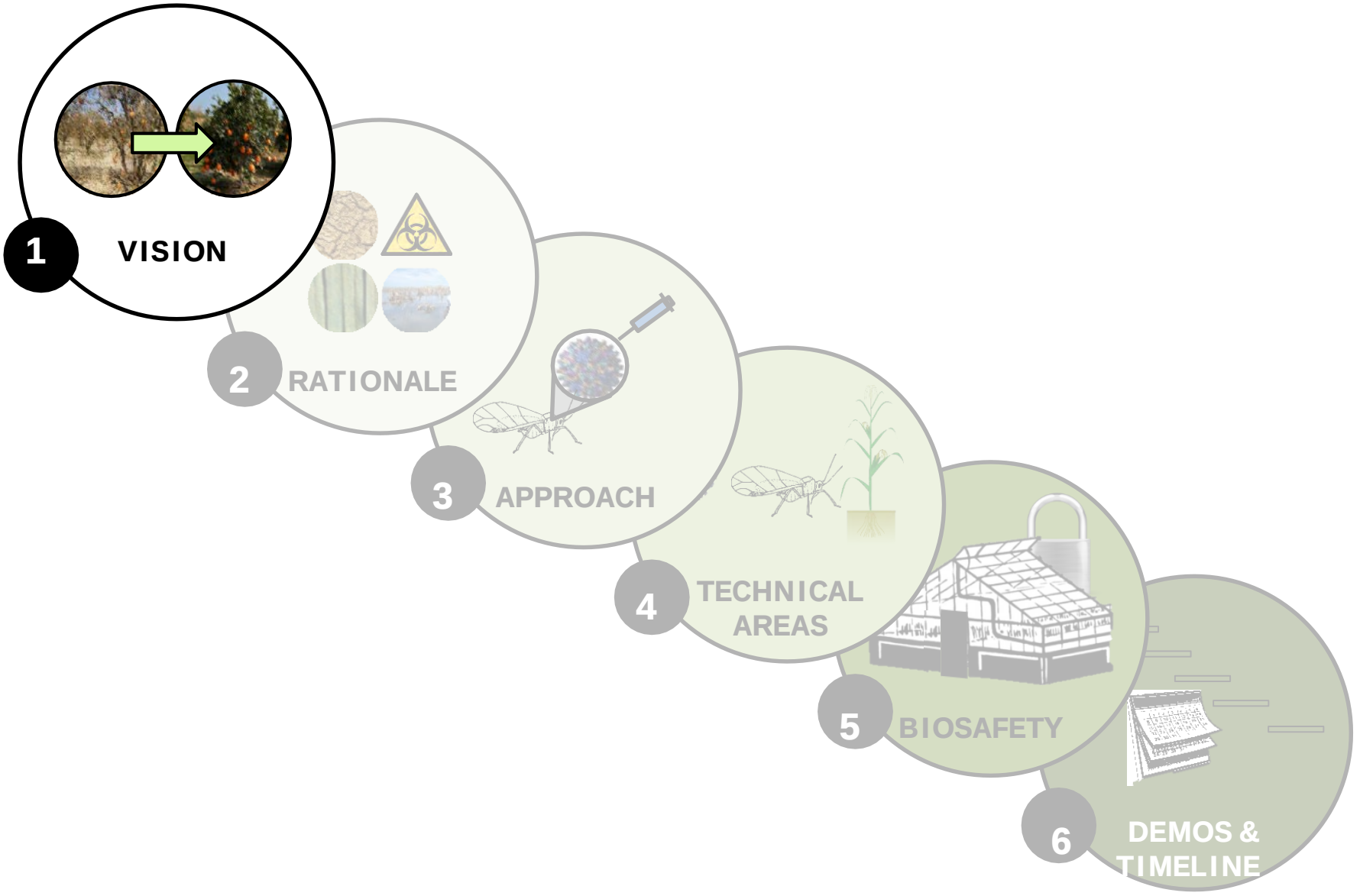
- To **facilitate interaction between investigators** that may have capabilities of interest and relevance to Insect Allies goals; and

- To **encourage and promote teaming arrangements** among organizations that have the necessary expertise, facilities and capabilities to meet research objectives established by the Insect Allies program.

Presentation Outline

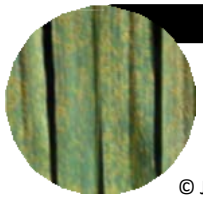


Presentation Outline

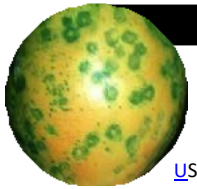


Agricultural Security is National Security

Biological


Fungus

© James Kolmer


Virus

USDA-ARS


Bacteria

© NIAID

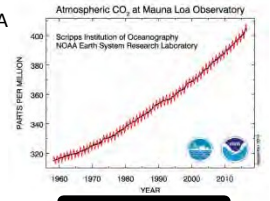

Insect

USDA

Sources of Vulnerability


NOAA

Commerce



NOAA

Climate

Agricultural Threat


Release


© Michael Pereckas

Disaster

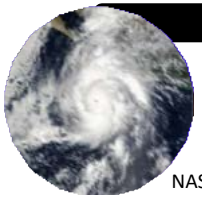
Environmental


Heat

© Axel Kristinsson


Flood

FEMA


Storm

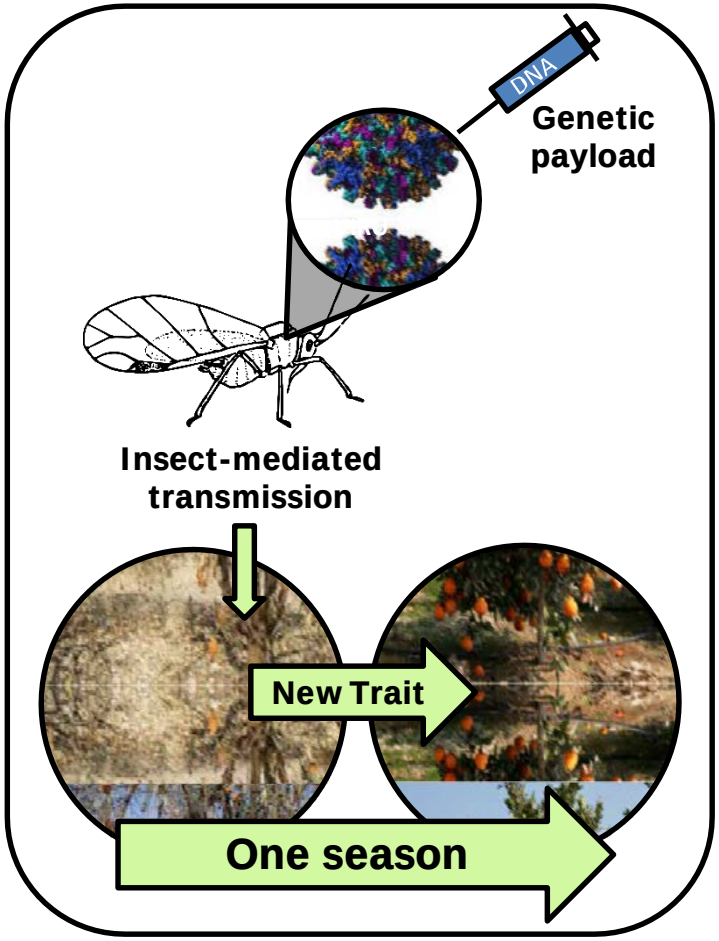
NASA


Geologic

USGS

Large-scale disruptions to the production of staple crops could particularly jeopardize food security.

Flexible, rapidly deployable mature plant modification platform at scale



Potential Applications:

- Introduce new plant characteristic to respond to the changing environment
- Protect plants from pest and pathogen incursion

Defense Rationale:

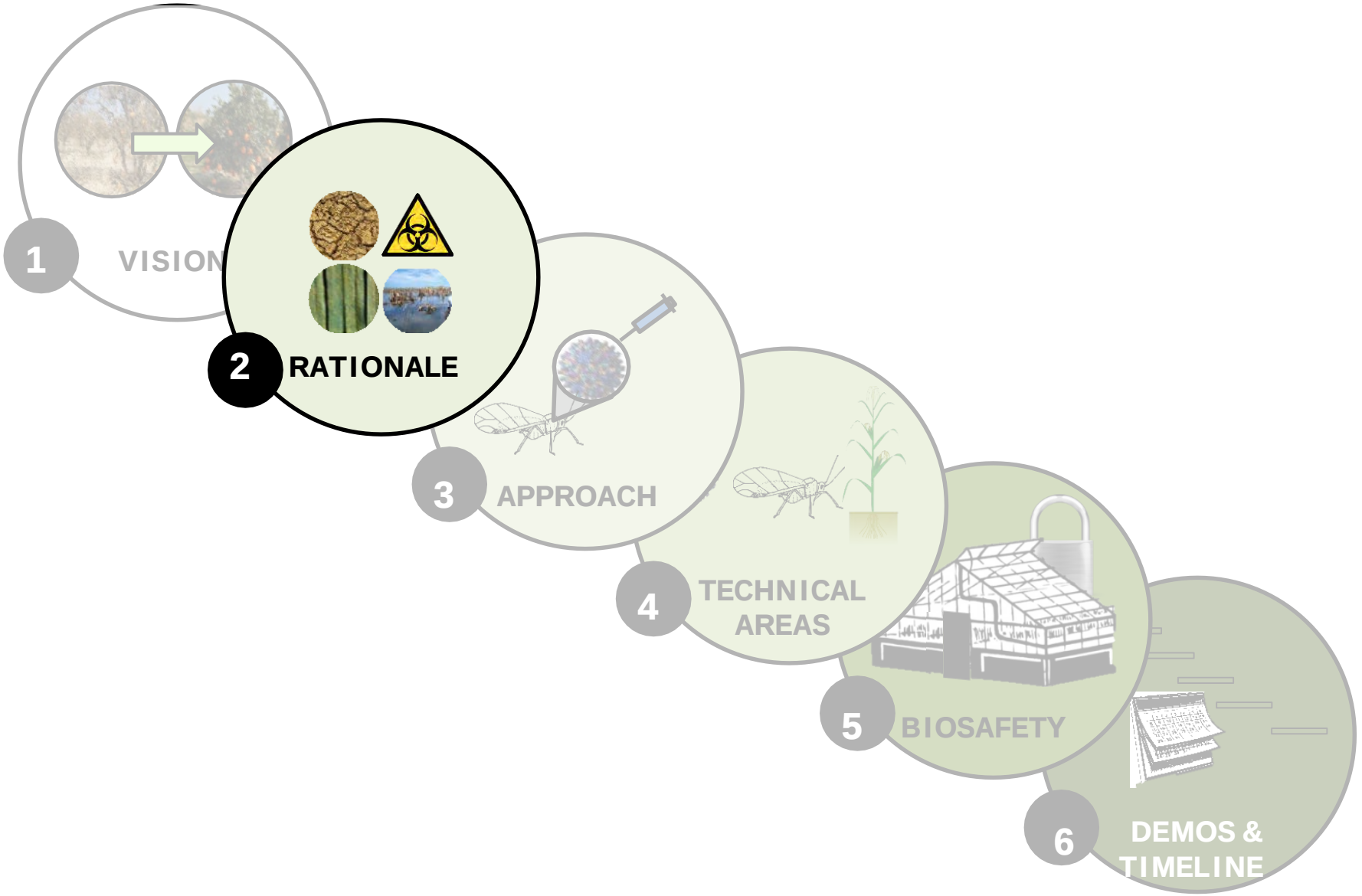
- Defend food security from accidental or purposeful biological threats
- Stabilize food supply in unstable regions

Impact:

- Shift plant protection paradigm
- Accelerate agricultural innovation

Goal: Use insects to disseminate targeted genetic payload to plant populations in one season

Presentation Outline



Challenges with current platforms

Selective Breeding

Specific gene introduction

Desired trait propagation

Selection: 5-7 Years

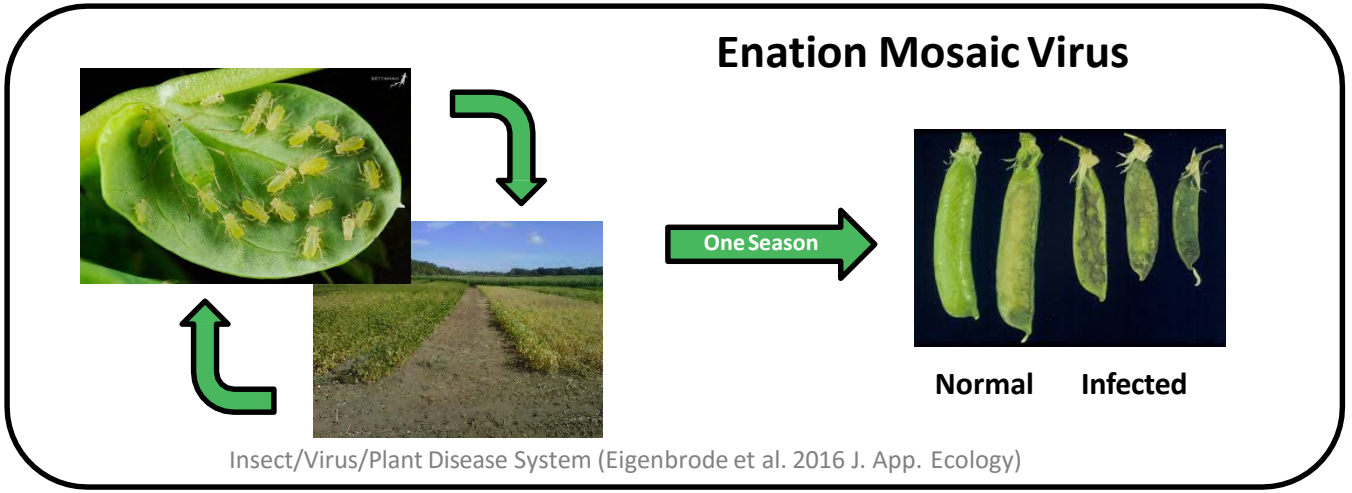
Scale up: 10-15 Years

Insect Allies will provide a rapid response platform to address agricultural challenges

Harnessing viral mechanisms to alter plant expression

Example natural system:

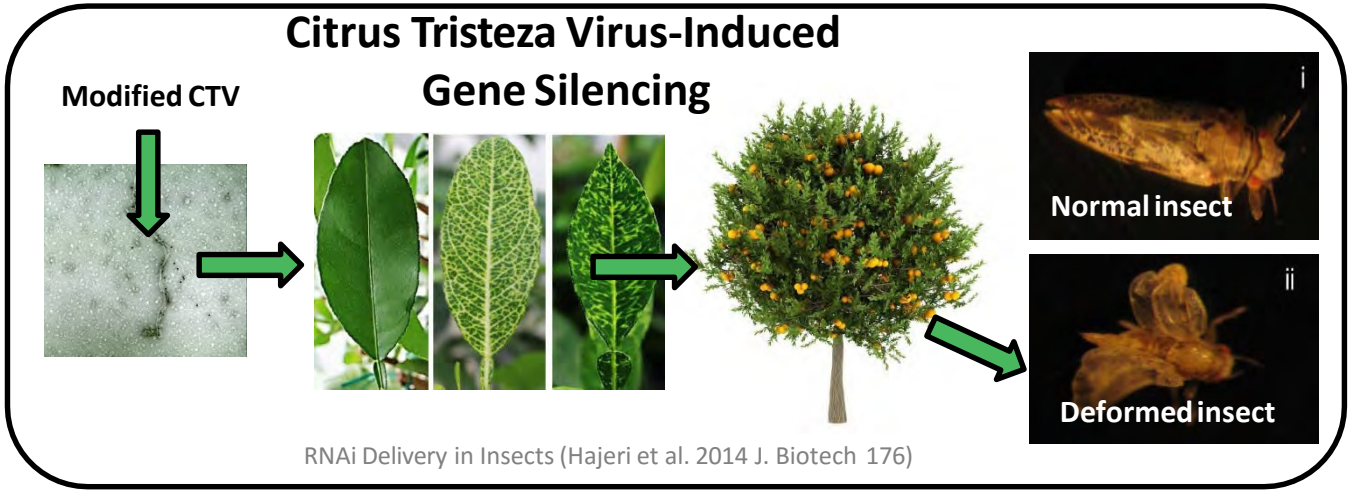
- Viruses rapidly alter plant phenology
- Often vector and target specific



Insect/Virus/Plant Disease System (Eigenbrode et al. 2016 J. App. Ecology)

Example engineered system:

- Virus-induced gene silencing to impact plant expression and pest viability

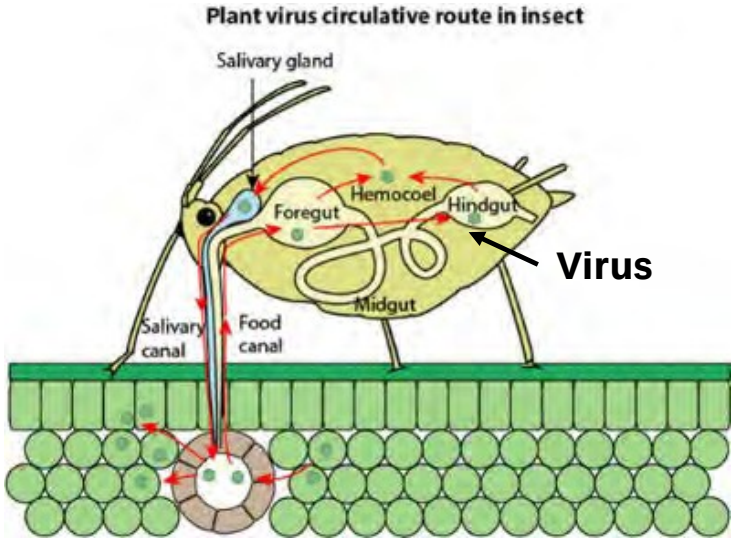


RNAi Delivery in Insects (Hajeri et al. 2014 J. Biotech 176)

Powerful viral tools require an innovative and targeted delivery strategy

Problem

- 50-80% of product lost to the environment
- Requires infrastructure
- Production prohibitive for genetic approaches



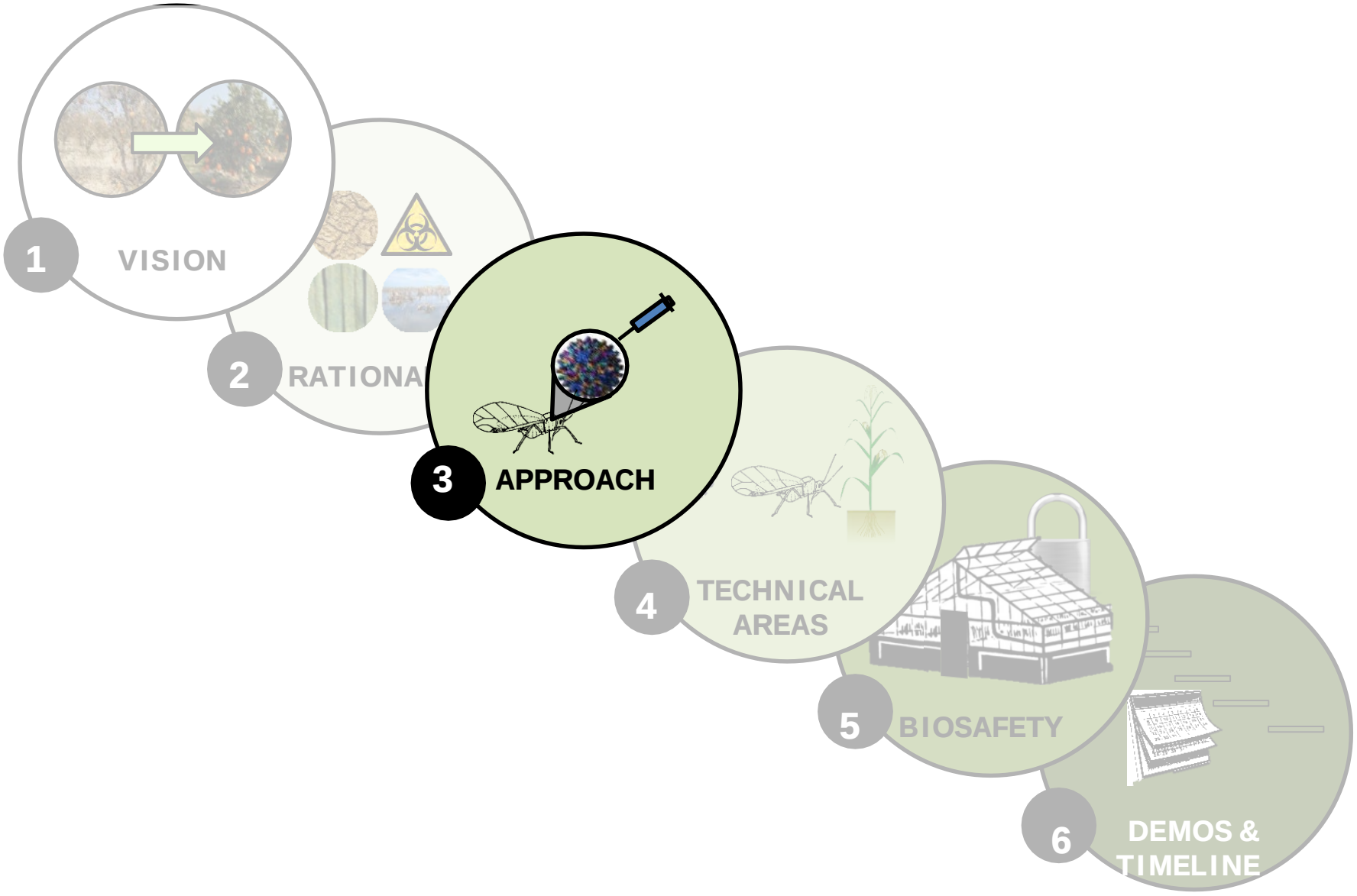
Solution

Insects carrying plant viruses have evolved to:

- Feed on specific plants
- Feed from specific tissues
- Have dynamic relationships with their viral community

Insect Allies will provide a platform to enable large-scale delivery of mature plant modification technology

Presentation Outline



Overarching Goals & Objectives

1. Select, modify, and optimize a **plant virus** that can deliver a genetic construct to mature target plants and ultimately **express novel and desirable traits**

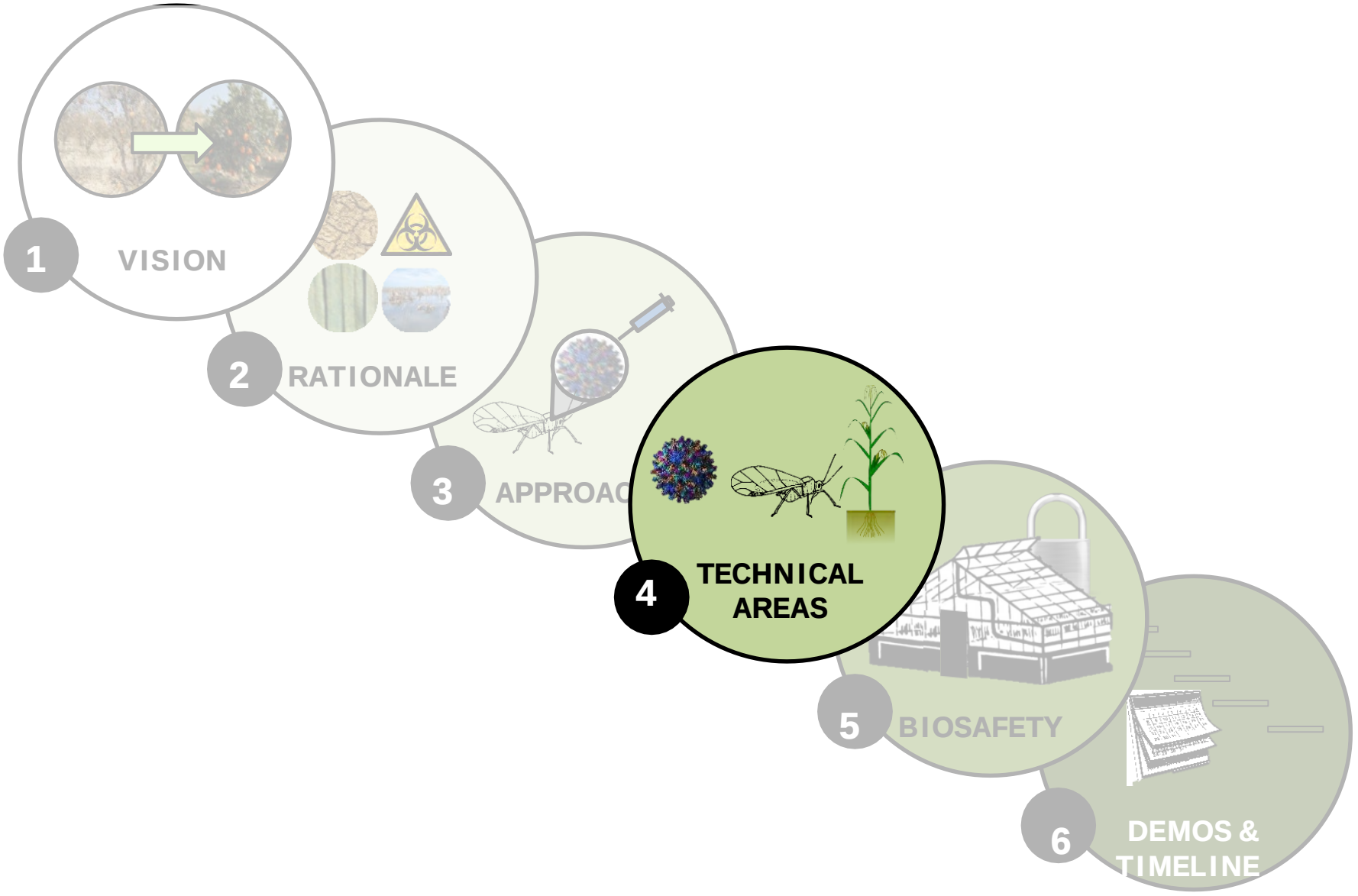
2. Select, culture, and optimize an **insect vector** of the engineered virus that can **transport and deliver the modified virus** to target plants with high specificity

3. Transform intact **mature target crop** plant species tissues to express novel traits that help crops **thwart expected environmental or biological threats**

By the end of the 4-year Insect Allies Program:

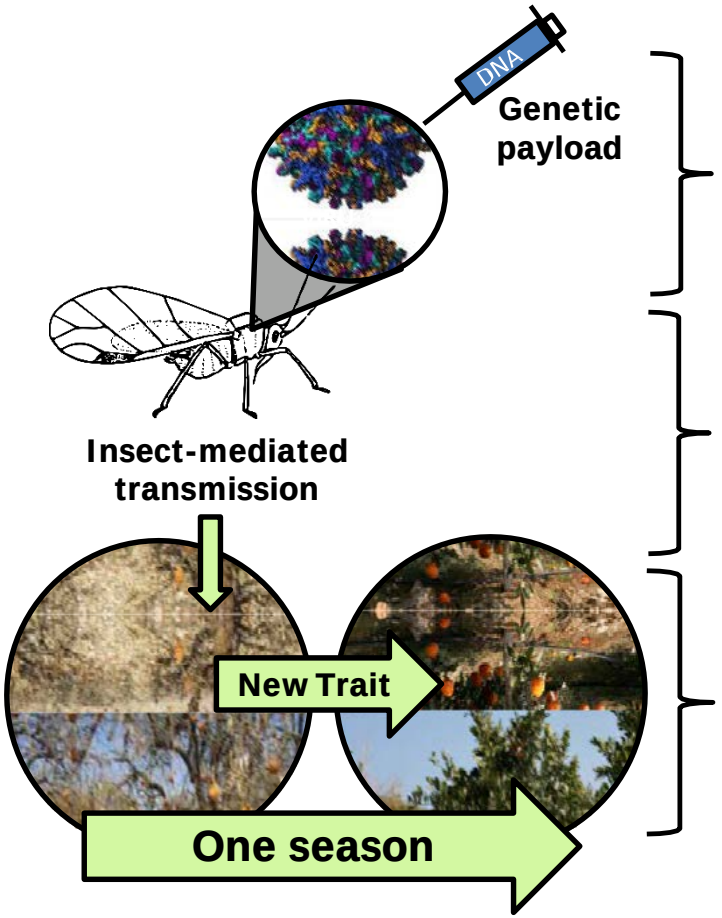
Stably transform multiple mature crop plants in a complex, multi-species plant and insect community with enhanced trait(s) of agricultural interest

Presentation Outline



Approach: Exploit the natural habits of Insect Allies

ALL Insect Allies proposals MUST address ALL THREE technical areas (TAs)



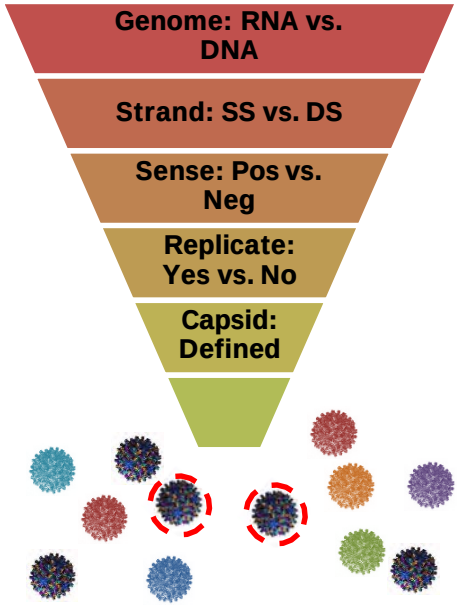
Technical Area 1: VIRUS → Novel Genetic Cargo Container

Technical Area 2: INSECT → Efficient Transport System

Technical Area 3: PLANT → Plant's Gain of Function

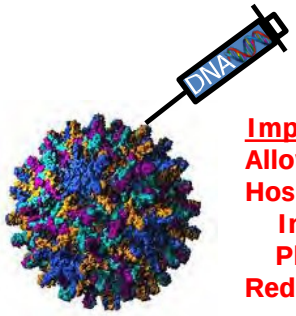
TA1: Virus – Novel genetic cargo container

Identify viruses with desirable characteristics



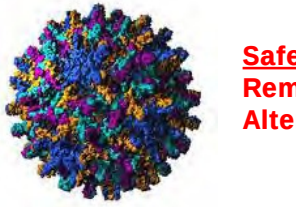
Hull (2014) Matthew's Plant Virology Academic Press, USA

Modify and optimize viral performance



Improve:
Allowable Cargo
Host Interaction
Insect
Plant
Reduce Error

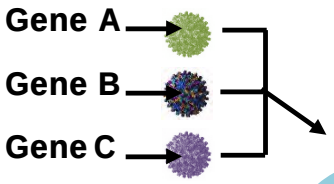
AND…



Safeguard:
Remove Pathogenicity
Alter Gene Stability

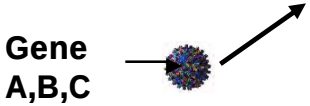
Hajeri (2014) J Biotech 176:42

Optimal payload delivery strategy



Efficient and controlled multi-gene delivery

OR



Maggio (2014) Scientific Reports 4:5105

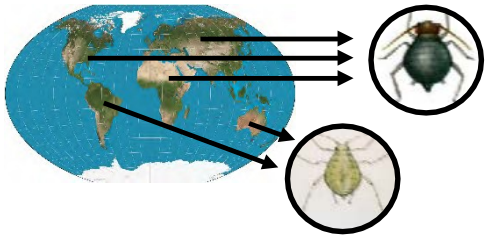
Proposer Developed Technology: Optimized viral delivery of gene editing technology

TA1: Virus – What success looks like

PHASE	OBJECTIVES	MILESTONES	METRICS
1	Produce a virus candidate library	Prospect viruses and provide rationale for virus choice(s)	5-10 candidate virus genomes sequenced and annotated
	Propagate virus(es)	Demonstrate successful virus propagation in culture	Demonstrate ability to manipulate growth in culture at significant levels
	Stabilize virus within the plant	Demonstrate stability of the genetically-modified plant virus within the plant	No significant viral transgene loss for ≥2 weeks
	Genetically modify plant virus	Quantify expression of single transgene	Significant transgene expression above control
2	Edit viral genome	Identify relevant promoter, terminator, spacer, and other important gene regulatory elements	Functioning viral multigene construct(s)
	Deliver multi-transgene capability	Quantify expression of ≥3 transgenes	Significant transgene(s) expression above control
3	Deliver and express systemic transgene(s)	Quantify the presence of multiple transgenes using relative gene expression of plant tissues	Significant transgene(s) expression above control

TA2: Insect – Efficient transport system

Identify and breed insects



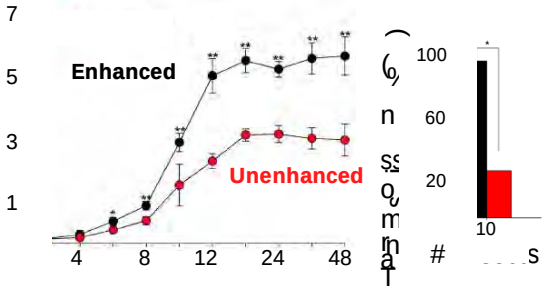
Select insects with optimal characteristics

⇩

Determine best practices for lab growth and experimentation

Optimize insect performance

Individual Vector Competence[1]



Population Mortality Rate[2] **and Community Dispersal Ability**[3]

1. Su et al. 2013 *Sci Report* 3:1367
2. Hedges et al. 2008 *Science* 322:702
3. Ingwell et al. 2012 *Sci Reports* 2:578

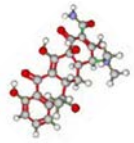
Install longevity safeguard(s)

Light sensitive

Time sensitive

Temperature sensitive

Diet regulated survival



Handler 2016 *Insect Science* 23:225-234

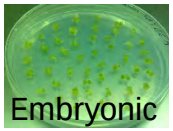
Proposer Developed Technology: Optimized insect vector system with built-in safeguards

TA2: Insect – What success looks like

PHASE	OBJECTIVES	MILESTONES	METRICS
1	Domesticate and select insect strains	Demonstrate insect culturing fitness data of selected strains with significantly reduced mortality	Mortality rates <30%
	Modulate and monitor transmission capability	Demonstrate molecular characteristics of vector competency; increase viral acquisition and transmission rates	Viral acquisition rate >75% Transmission rate >10%
2	Increase modulation of transmission capability at scale	Demonstrate molecular characteristics of vector competency; reduced mortality rates, increased transmission rates	Mortality rates <10% Transmission rate >30% Small greenhouse context (proposer defined)
	Implement single safeguard	Demonstrate elements of an effective (two-week window) single conditional lethal	Single conditional lethal (proposer defined) No significant survival
3	Deliver virus community-wide	Demonstrate delivery to majority of target plants in less than 48 hours with no measurable off-target effects	>50% target prevalence No transgene expression in non-target plants Large greenhouse context (proposer defined)
	Implement multi-safeguard	Demonstrate elements of an effective multiple conditional lethal with no significant insect survival after 2 weeks	Multi-conditional lethal (proposer defined) 0% survival after a user defined time where 50% of non-transformed insects survive

TA3: Plant – Plant's gain of function

Improve tissue modification

Gene(s) → 

Gene(s) → 

Challenges:
- Systemic distribution
- Multi-tissue alteration

Brooks (2014) Plant Phys 166:1292

Mature plant modification

Demonstrate mature plant modification in a greenhouse setting

⇩

Validate transformation resulting in altered traits

Masoni (2014) Plos One 9:e96831v

Selective modification

Trait induction to large monoculture of plants

⇩

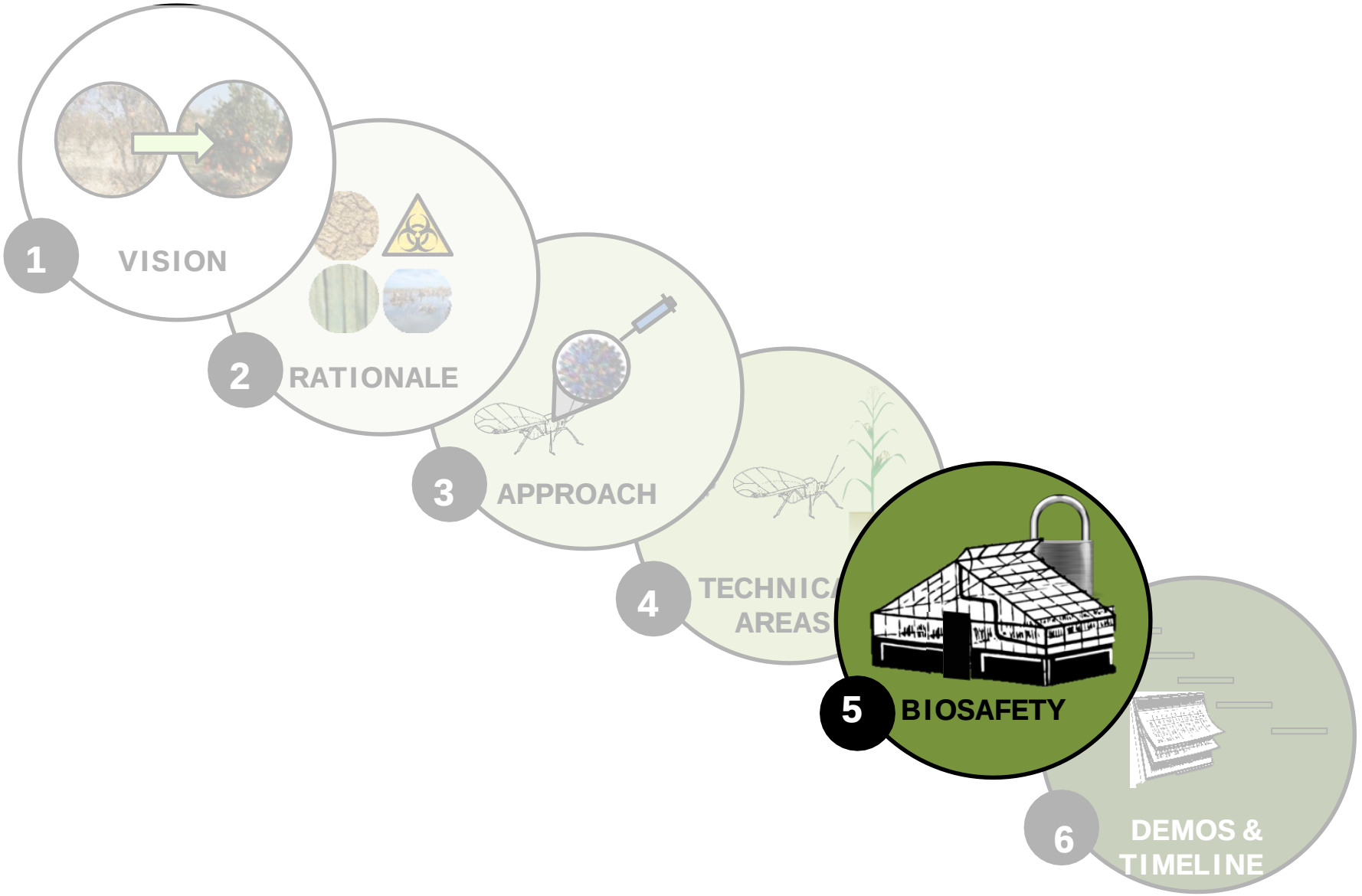
Confirm trait enhancement within diverse community

Proposer Developed Technology: Rapid and scalable mature plant modification

TA3: Plant – What success looks like

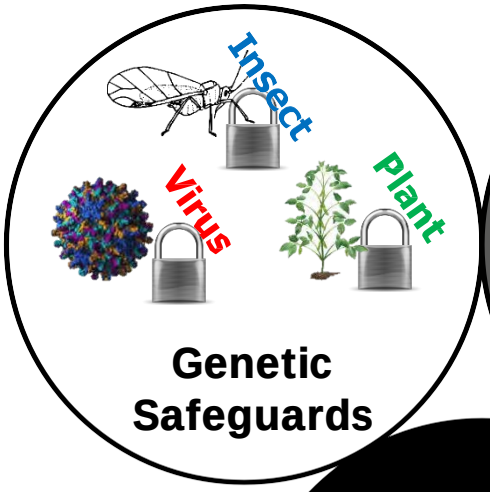
PHASE	OBJECTIVES	MILESTONES	METRICS
1	Modify mature plant tissue	Quantify characteristics of mature plant tissue and transgene expression	Transgene expression 50% above control in mature tissue type
2	Validate modification parameters in monoculture	Quantify expression of transgenes	≥3 delivered transgenes expression above control
3	Demonstrate enhanced trait in target plants within community context	Quantify expression of transgenes with no off-target effects in community	>50% of targeted plant population is successfully genetically modified within ≤1 week with no detection of off-target effects to other community organisms

Presentation Outline

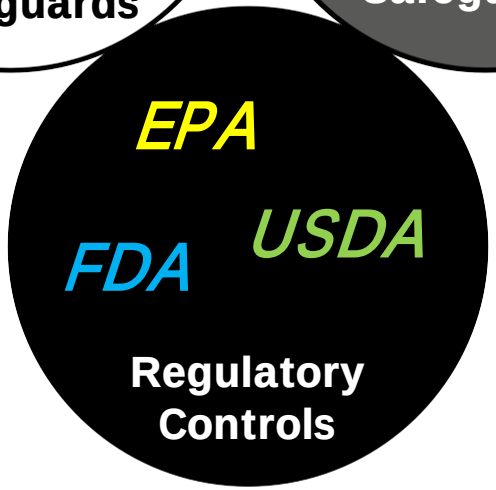


Biosafety Design and Data Sharing

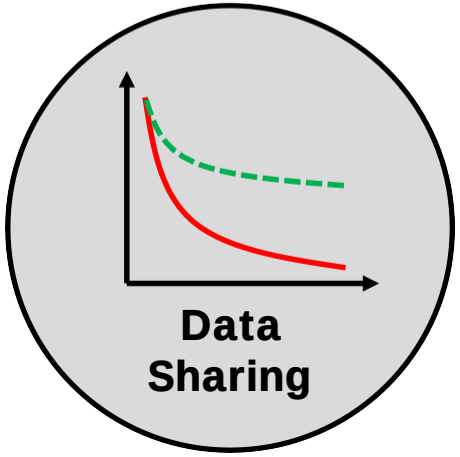
Performers are ***required to include genetic safeguards*** (e.g. transgene degradation, conditional lethal systems) into their research and implementation program.



All research will be conducted in ***contained environments*** and DARPA will not support any proposals that include uncontained environmental release of such organisms.

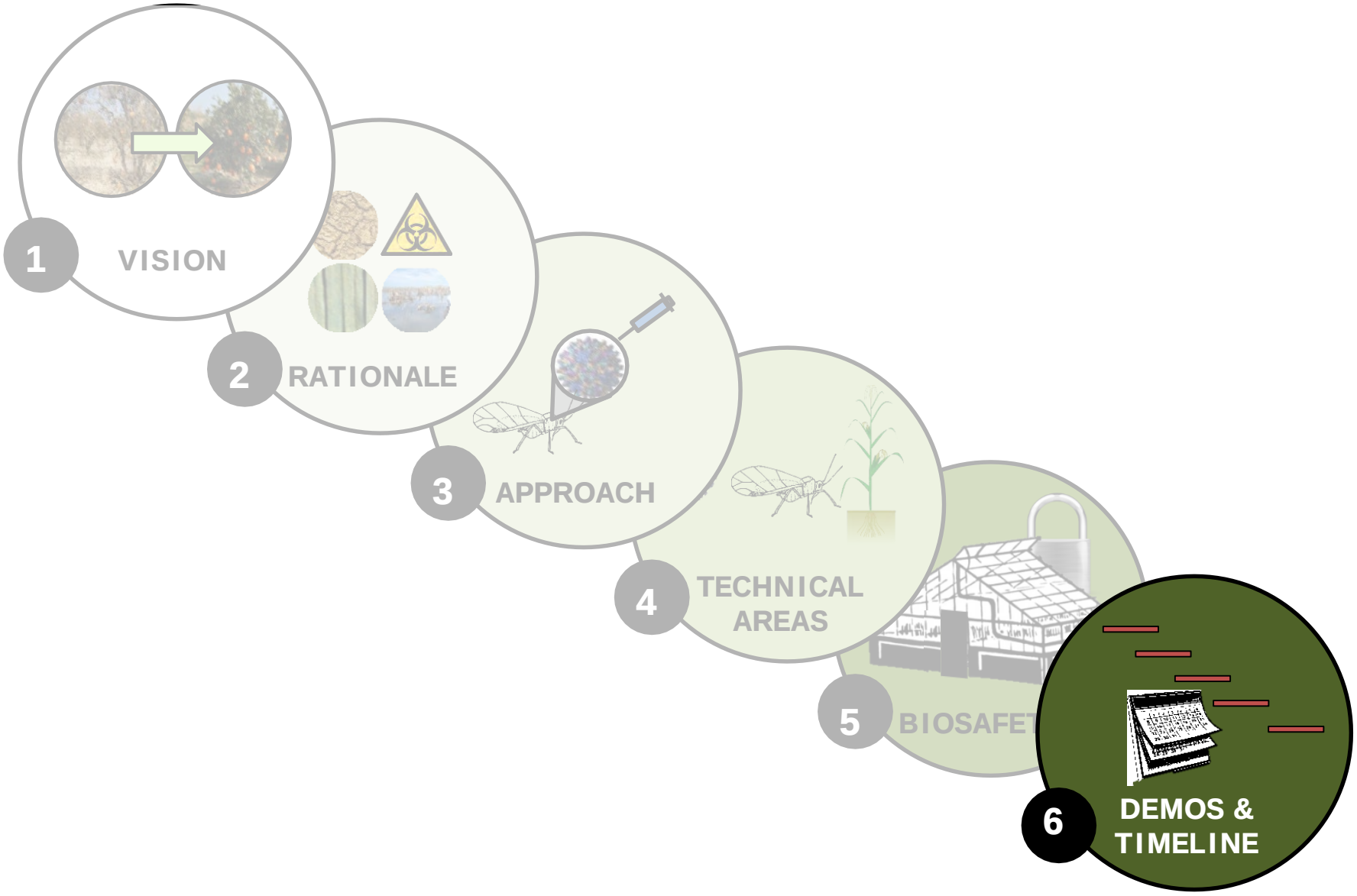


Insect Allies performers are ***strongly encouraged*** to proactively engage with all relevant regulatory agencies during the design and implementation of their research program.

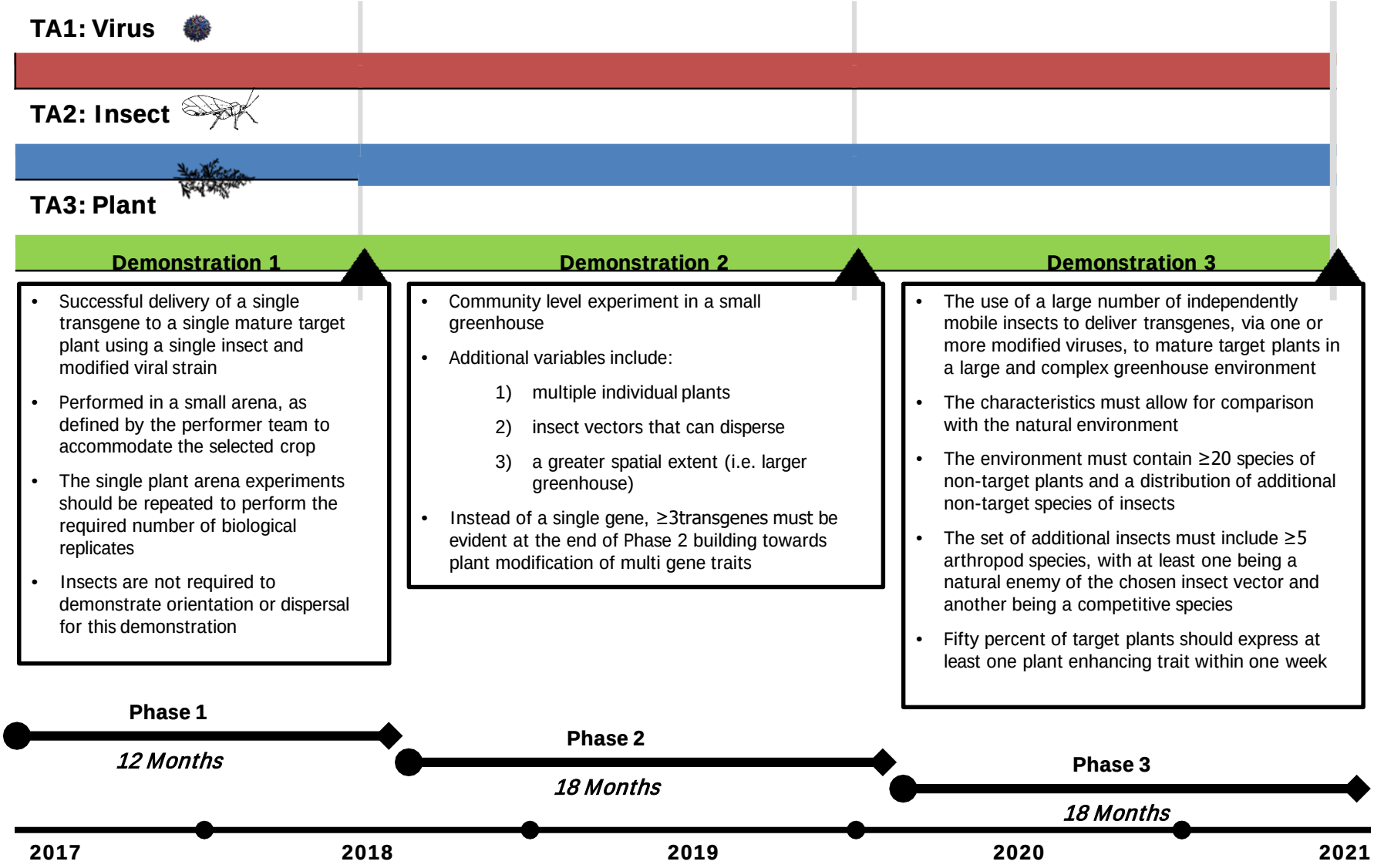


Performers are ***strongly encouraged*** to establish the appropriate agreements to enable collaboration and data sharing, including pre-existing data generated through funding by other sources, although this is not a requirement of the program.

Presentation Outline



Example Milestone Timeline



DARPA Acronym Glossary

Term	Definition
BAA	Broad Agency Announcement: Document outlining proposal expectations, similar to RFP (Request for Proposals) from other funding agencies.
Technical Area or TAs	Domains of scientific or engineering investigation or practice that are required to be included as part of DARPA BAA proposals and execution.
Phase	Temporal period of a proposal/contract with specific goals/emphasis
Demonstration	A demonstration, typically at the end of a contract phase, that meets measureable milestones as outlined in DARPA BAAs
Proposal Abstract	A concise version of the proposal comprising a maximum of 8 pages including all figures, tables, and charts.
Proposer	Those submitting a proposal to a DARPA BAA
Prime/Lead PI	The primary lead/POC in a BAA proposal and subsequent contract
Sub/Co-PI	A subordinate (to the prime) lead/POC in a BAA proposal and subsequent contract
POC	Point of Contact
SOW	Statement of Work: provide a detailed task breakdown, citing specific tasks and their connection to the interim milestones and program metrics. Each phase of the program should be separately defined. The SOW must not include proprietary information.
Program Manager	DARPA leadership position at the office level. Define their own programs, set milestones, meet with their performers and assiduously track progress.
DARPA	Defense Advanced Research Projects Agency
BTO	Biological Technologies Office. One of six DARPA offices.
SETA	Scientific Engineering and Technical Assistance: Junior DARPA position that acts in professional/expert support to offices and program mangers.
DOD	United States Department of Defense

Insect Allies BAA

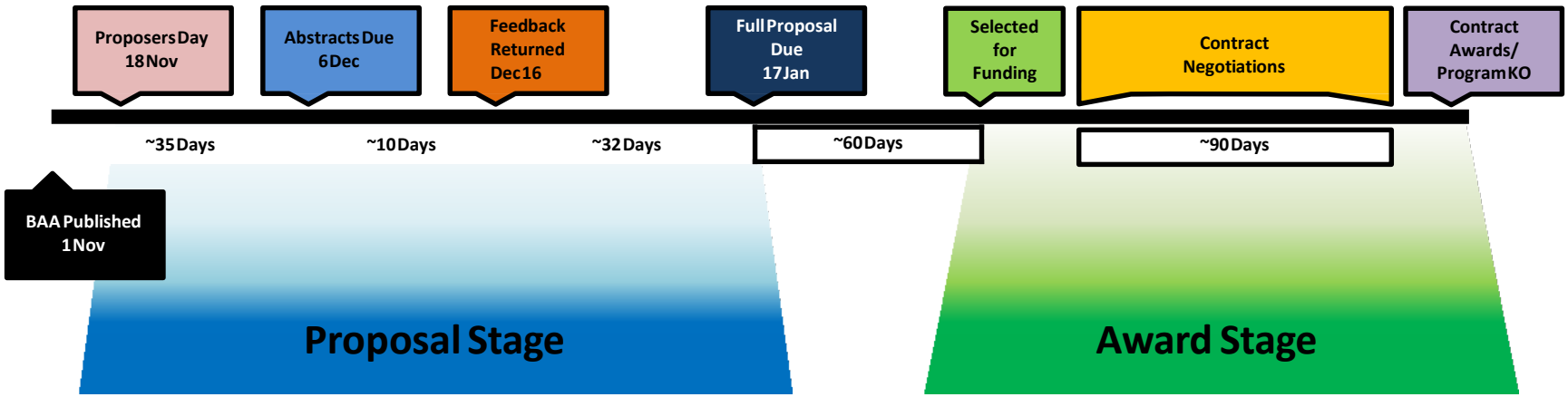
HR001117S0002

Slides will be available at the registration website shortly

Insect Allies BAA

- Proposal Abstract Format
- Proposal Abstract Components
- Full Proposal Content
- Cost Proposals
- Proposal Review Process
- Teaming
- FAQs
- Final bits of advice

How to approach a DARPA BAA



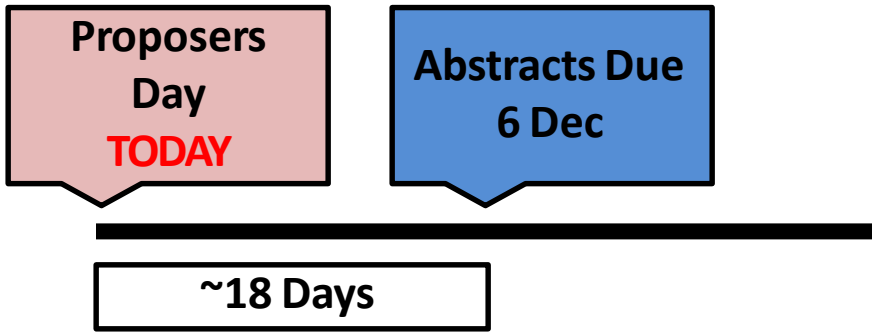
Read the BAA, **carefully** – and respond accordingly.

- Some instructions are specific – **"required" and "must"**
- **Most of the instructions are non-specific** – you decide on what is the best possible science to support the objectives of the program
- Be **honest** about risks and demonstrate thoughtful consideration for how to mitigate those risks.

Ask for clarification as needed. FAQs will be updated regularly.

Take advantage of today's opportunities to meet potential teammates and ask questions

Proposal Abstract Format



Abstracts are strongly **encouraged,** but optional.

You may submit a full proposal even if you did not submit an Abstract

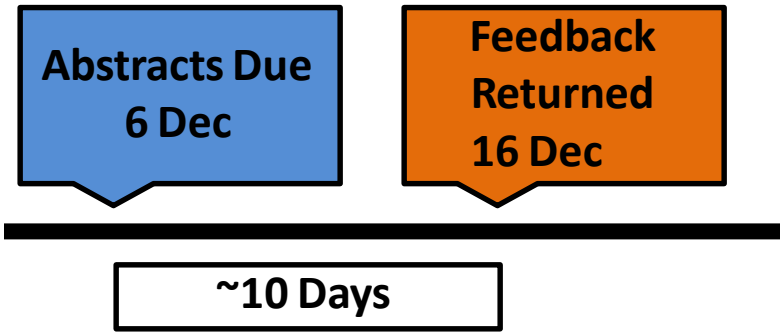
8 Page Total

Abstracts should include:

- Goals and Impact
  - What are you trying to do?
  - What is innovative in your approach?
  - How does it compare to the state of the art?
  - How much will it cost and how long will it take?
- Technical Plan
  - Outline your statement of work
  - Outline the critical risks
  - Provide specific milestones
- Capabilities
  - Team composition
  - Demonstrated translational success

"DARPA will respond to abstracts with a statement as to whether DARPA is interested in receiving a full proposal."

Proposal Abstract Components



Abstracts must include the following components:

8 Page Total

A. Cover Sheet
B. Executive Summary
C. Executive Summary Slides (Attachment 1 to the BAA)
D. Technical Plan
E. Management and Capabilities
F. Cost and Schedule
G. Resumes

For more abstract details see BAA pg. 17-19

Full Proposal - Technical & Management

Abstract Feedback 16 Dec

Full Proposal Due 17 Jan

~32 Days

40 Page Total

Nonconforming proposals maybe rejected without review

Volume I – Technical and Management Proposal

Section I Administrative

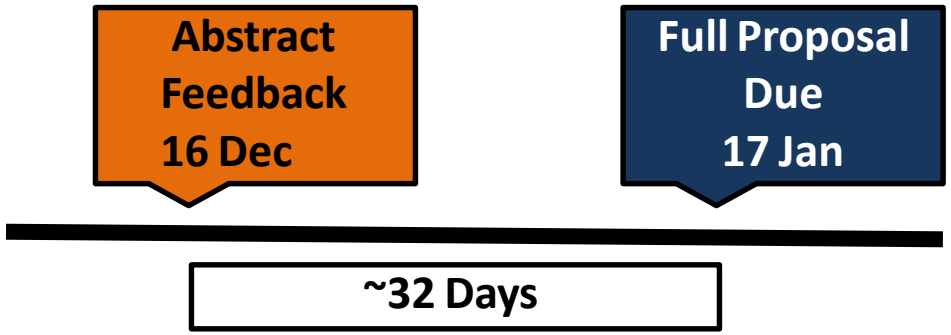
A. Cover Sheet
B. Official Transmittal Letter
C. Executive Summary Slides (attachment 2 to the BAA)
D. Program Plan Summary (attachment 3 to the BAA)

Section II Detailed Proposal Information

A. Executive Summary
B. Goals and Impact
C. Technical Plan
D. Management Plan
E. Capabilities
F. Statement of Work (SOW)
G. Schedule and Milestones

Include resume or biosketch for all key personnel

Full Proposal – Cost



No Page Limit

Nonconforming proposals maybe rejected without review

Volume II – Cost Proposal

- Detailed cost breakdown by:
  a. Major program tasks by government fiscal year
  b. Total program cost by phase and task
  c. Projected funding required by month
  d. Itemization of Information Technology (IT) purchase
- Don't forget travel funds for all key personnel to attend the Kickoff Meeting and semi-annual PI Review meetings.
- Subcontractor proposals **must** be prepared at the same level of detail as that required of the prime.

Cost proposal does not have a page limit

For more proposal details see BAA pg. 20-26

Estimating your costs

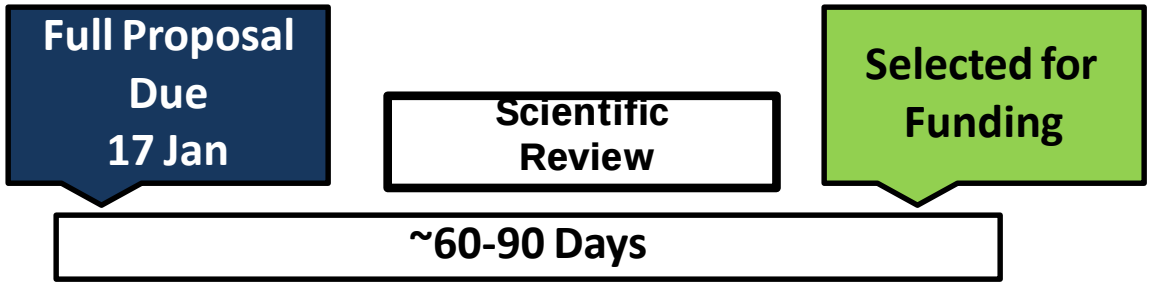
DARPA will not provide feedback regarding dollar amounts -- you tell us what it will cost to perform the proposed research.

Additional guidance will be provided after proposal abstracts are evaluated.

Evaluators are instructed to consider that "**The proposed costs are realistic for the technical and management approach and accurately reflect the technical goals and objectives of the solicitation.** The proposed costs are consistent with the proposer's Statement of Work and reflect a sufficient understanding of the costs and level of effort needed to successfully accomplish the proposed technical approach. The costs for the prime proposer and proposed subawardees are substantiated by the details provided in the proposal." (BAA pg. 30)

"DARPA recognizes that undue emphasis on cost may motivate proposers to offer low-risk ideas with minimum uncertainty and to staff the effort with junior personnel in order to be in a more competitive posture. DARPA discourages such cost strategies." (BAA pg. 30)

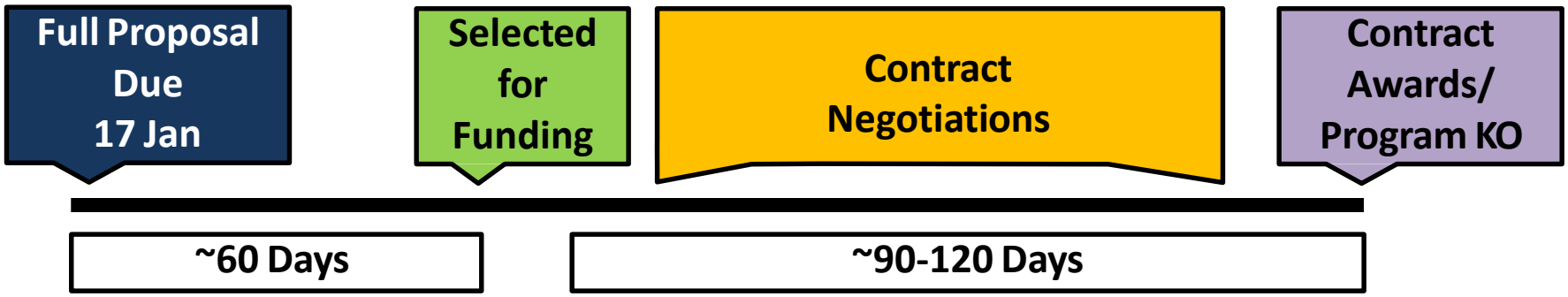
Full Proposal Review Process



- Scientific Review by government personnel from DARPA, USDA, EPA, US Army, and other US Government agencies.
- Proposals are not ranked, but evaluated for strengths and weaknesses with respect to the criteria published in the BAA:
  a) Overall Scientific and Technical Merit
  b) Potential Contribution and Relevance to the DARPA Mission
  c) Proposer's Capabilities and/or Related Experience
  d) Cost Realism
- Program Manager recommends proposals for funding.

See BAA pg. 29-30 for details regarding proposal evaluation

Award Stage: Timeline Horizons



- Contract negotiation timelines depend on each institution/organization's response time.
- The contracting office will contact the selected performers and begin the contracting process.

- Anticipated Insect Allies program kick off date is late June/early July 2017

Teaming

DARPA strongly encourages establishing teams to address all technical areas to ensure the expertise and capabilities necessary to meet program goals.

- You must **find your collaborators on your own.** Specific content, communications, networking, and team formation are the sole responsibility of the proposer teams.
- It is **expected that proposals will involve multidisciplinary teams** that include expertise from multiple complementary disciplines (e.g., virology, vector entomology, and plant biotechnology).
- Your **team must submit a single, integrated proposal** led by a single Program Integrator/ Manager or prime contractor that addresses all program Phases and TAs, as applicable.

This BAA is open to educational institutions, government labs, and/or private companies.

Foreign entities may join a team or submit as the Program Integrator/Manager or prime contractor.

If you are a member of a team, you may join any number of other teams or form your own and submit a proposal as PI.

Note that the cost volume for each team member must be at the same level of detail as for the Program Integrator/ Manager or prime contractor.

BAA Inbox and FAQ

Direct **ALL** questions and communications to the BAA Inbox Insectallies@darpa.mil

Dr. Bextine, any member of his team, or the BAA Inbox **cannot provide feedback or guidance on any aspect of your proposal, they can only clarify the content of the Insect Allies BAA** (HR001117S0002)

DARPA will update the Insect Allies FAQs on a regular basis and can be found on the DARPA Opportunities web page:

http://www.darpa.mil/work-with-us/opportunities?tFilter=&oFilter=1&sort=date

All **questions must be submitted at least 15 days prior** to the proposal submission deadline **(January 17, 2017)**

Final bits of advice

Read the BAA over and over again and follow all instructions carefully.

A successful proposal addresses **all aspects** of the BAA.

- Pay attention to "**must**", "**should**", "**shall**", and "**all**" in the BAA.
- Incomplete proposals will not be evaluated.

DO NOT try to **shoehorn ongoing, but not applicable, work into the BAA.**

DO NOT submit a **rewritten USDA, NIH or NSF proposal.**

DO NOT propose to do anything that is **not directly relevant to the BAA.**

DO NOT submit **an irrelevant or incomplete proposal** in the hope we'll fund it anyway.

A proposal abstract is **HIGHLY RECOMMENDED.**

AGENDA

Start	End	Duration	Item
8:30 AM	9:00 AM	0:30	Registration
9:00 AM	9:15 AM	0:15	Welcome, Introductions and Logistics Dr. Blake Bextine, Program Manager, DARPA/BTO Ms. Renee Besanson, Meeting Coordinator
9:15 AM	9:30 AM	0:15	Remarks from BTO Leadership Dr. Justin Sanchez, Director, DARPA/BTO
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10:15 AM	10:45 AM	0:30	Insect Allies BAA Overview Dr. Blake Bextine, Program Manager, DARPA/BTO
10:45 AM	**11:00 AM**	**0:15**	**Break**
11:00 AM	11:30 AM	0:30	Working with DARPA Mr. Mike Mutty, DARPA/CMO Mr. David Swan, BAA Coordinator/DARPA/BTO
11:30 AM	11:50 AM	0:20	Guest Speaker Dr. Sonny Ramaswamy, Director, National Institute of Food and Agriculture
11:50 AM	12:10 PM	0:20	Guest Speaker Dr. Jacqueline Fletcher, National Institute for Microbial Forensics & Food and Agricultural Biosecurity
12:10 PM	1:00 PM	0:50	Working Lunch/Networking/**Questions collected** by the DARPA team Questions to be answered at the 3pm Question & Answer review session
1:00 PM	3:00 PM	2:00	Lightning Round Talks Proposer Introductions (3 min. each)
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3:30 PM	4:30 PM	1:00	Additional time for poster review/team networking
4:30 PM			Closing remarks/Meeting Adjourns

www.darpa.mil

Contracting with DARPA

Mike Mutty
Contracts Management Office

David Swan
BAA Administrator, BTO

Insect Allies Proposers Day

November 18, 2016

• READ THE BAA

- Drafting the BAA
  - Words are Meaningful
  - Must and Shall
  - May
- Technical vs Administrative
  - Technical Leads to “Selectable”
  - Administrative Leads to Contract Award
    - Cost Proposal
    - IP Assertions

Proposal Preparation and Submission

- Instructions are detailed in the BAA (**Follow closely**)
- **ALL** questions to InsectAllies@darpa.mil
- FAQ (including today's) will be available on the DARPA Opportunities page
- Assert rights to **all** technical data & computer software generated, developed, and/or delivered to which the Government will receive less than Unlimited Rights
- If you don't justify your proposed costs, we can't justify awarding you a contract.
  - Pay close attention to cost proposal instructions

Evaluation Criteria and Award

Read evaluation criteria carefully

1. Overall Scientific and Technical Merit
2. Potential Contribution and Relevance to the DARPA Mission
3. Proposer's Capabilities and/or Related Experience
4. Cost Realism

Evaluation and Award

- Government reserves the right to select for award all, some (partial selection), or none of the proposals received.
- Government anticipates making multiple awards
- No common Statement of Work - Proposals evaluated on individual merit and relevance as it relates to the stated research goals/objectives rather than against each other

Process Overview

BAA Questions

Direct all questions and communication to the BAA inbox

- Insect Allies@darpa.mil
- Submit questions **at least 15 days** prior to the proposal submission deadline

The Program Manager or any member of the scientific review panel will not communicate directly with a potential proposer regarding the Insect Allies BAA

- The DARPA team will provide feedback and/or guidance to clarify content of the BAA only and cannot provide feedback regarding any aspect of a proposal

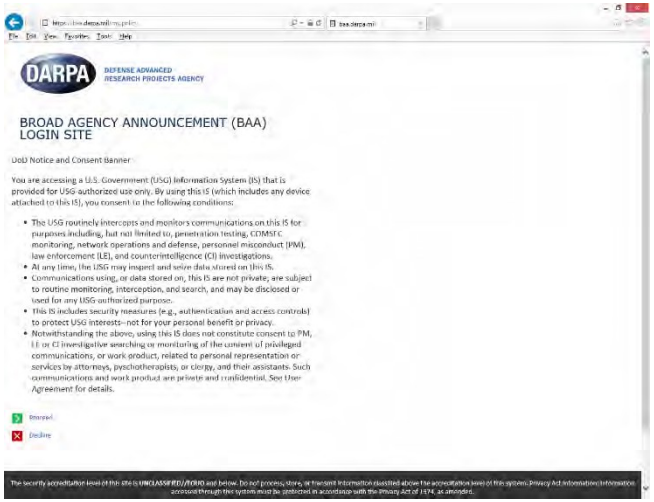
BAA Inbox – InsectAllies@darpa.mil

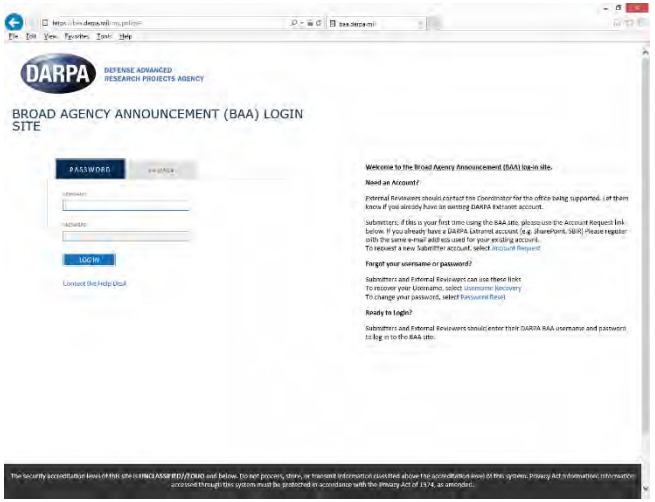
- Before submitting a question, you should...
  - Read the BAA
  - Understand that you'll get a clarification, not an idea
  - *Re-read the BAA*
  - Understand that you won't get any information from a competitor
  - **Study the BAA**
  - Understand that your question will likely be added to the FAQ
- Memorize the BAA!!!

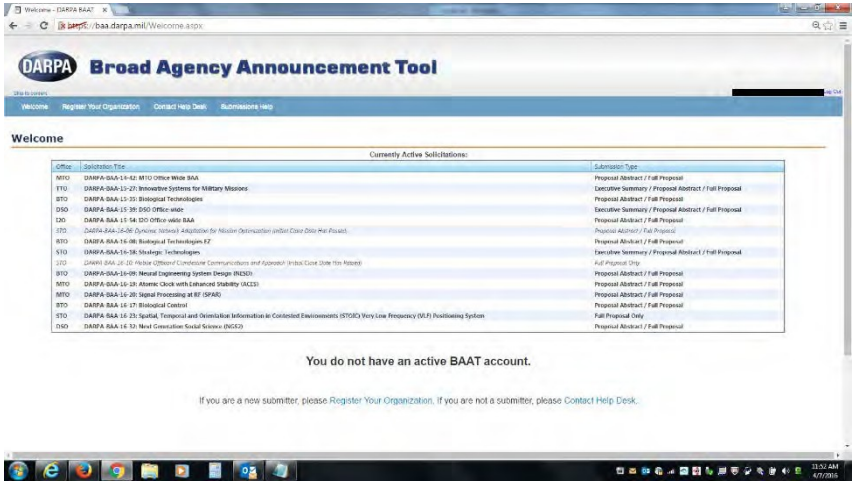
Submission Specifics

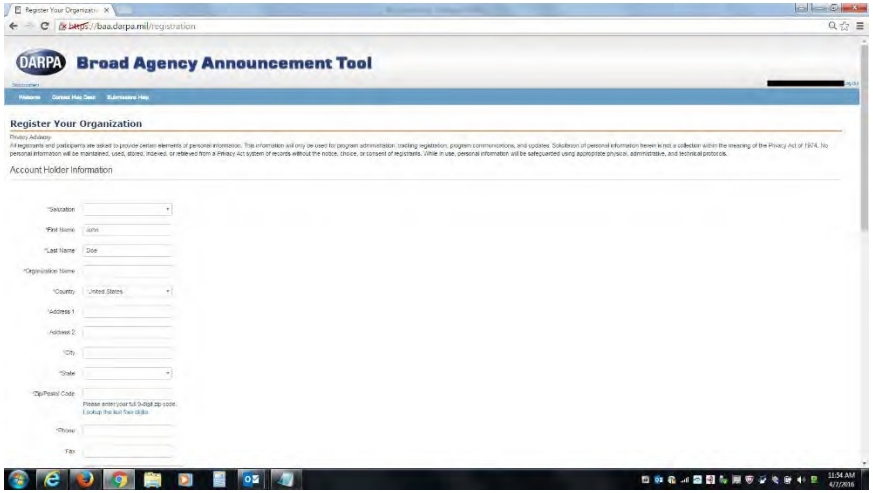
- NO submissions via fax/e-mail
- Grants & Cooperative Agreements – Grants.gov
- All other Award Instruments – DARPA BAA Portal (https://baa.darpa.mil)
- Start Today ☺
- Only attach attachments

DARPA BAA Portal









Please submit questions during the break.

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Insect Allies Proposers Day
November 18, 2016

Crop Biosecurity

Safeguarding a Critical U.S. Infrastructure

Jacqueline Fletcher
National Institute for Microbial Forensics & Food and Agricultural Biosecurity
Oklahoma State University

Crop vulnerability to threats: NAS Report 2002

- U.S. agriculture is **vulnerable** to emerging pathogens and pests
- Crops generate:
  - 1/6 of our gross domestic product
  - 17% of our employment
- ~ 65% of U.S. crop losses are due to introduced pathogens
  - This costs over **$137 billion/year**
- Many crops are planted as **monocultures**
  - **Low genetic diversity** increases the potential for damage

Image credit: German Cheung / Bigstock

Image credit: richardmasoner via Flickr

Plant systems are affected by:

- Pathogens

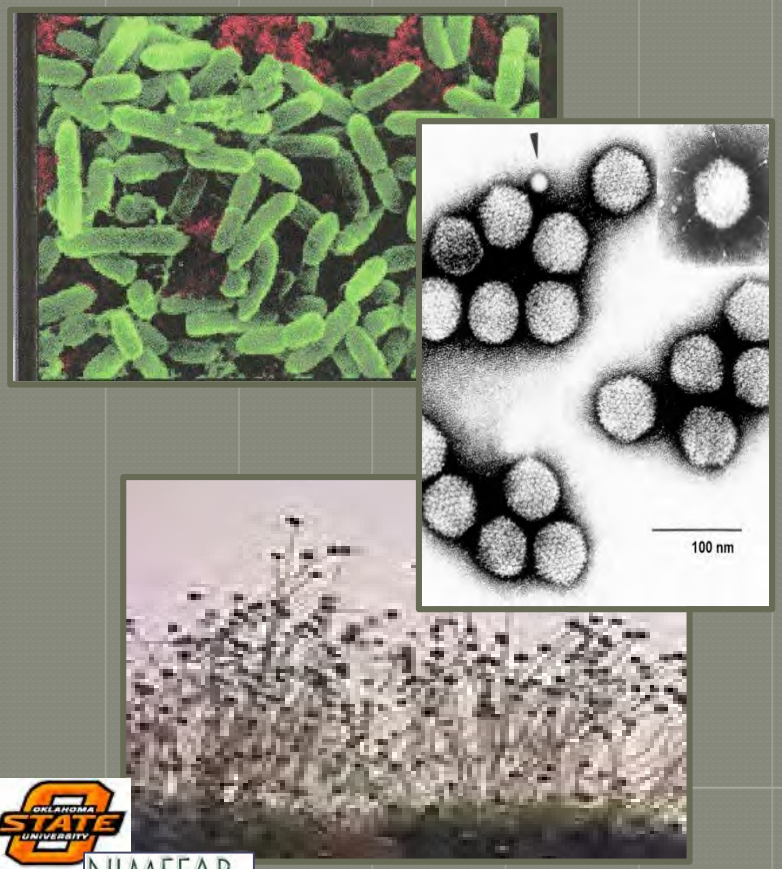

Image credits: James A. Sullivan / CELLS alive!; International Committee on Taxonomy of Viruses; Florence Caitlin Hodges / SlidePlayer

- Insect herbivores & vectors

Image credits: Illinois Natural History Survey; USDA ARS; http://www.naturescontrol.com/

Threats to crops:
Climate change will affect food security through impacts on all aspects of global, national & local food systems

-Climate Change and Food Security: A Framework Document. -FAO, United Nations, 2008.

THE SAINSBURY LABORATORY

Threats to crops: Emerging pathogens

Example: Citrus canker & citrus greening in Florida

Citrus greening

Citrus canker

Citrus is a **billion $** industry in Florida, but it is struggling to cope with hurricanes, freezing temperatures and several plant diseases and insects

Florida Citrus Production

Citrus Crop Year	Sales On-Tree Value
2013-2014	$946,454,000
2012-2013	$1,154,763,000
2011-2012	$1,640,423,000
2010-2011	$1,368,626,000
2009-2010	$1,131,107,000
2008-2009	$1,046,735,000
2007-2008	$1,283,994,000
2006-2007	$1,499,112,000

Image credits: USDA APHIS; Florida Department of Agriculture and Consumer Services

Initial management strategy for canker: Eradication of diseased trees… *AND* trees within a 1900 ft radius

Gottwald et al 2002

- **Goal**: Eradication
  - ***Successful in the past, considered possible***
- Growers were in favor, but wealthy homeowners resisted removal of dooryard citrus
- Legal action impeded implementation of eradication efforts

USDA APHIS switch: Eradication to disease management

Image credits: USDA ARS; NASA

- Cost:
  - over $200 million spent
  - over 10,000,000 trees destroyed
- Disease continued to spread
- 2005 hurricanes changed everything – ***and more frequent extreme weather events are expected to accompany climate change***
- **Citrus greening** arrived in FL (2005)
- **Eradication strategy** was changed to a comprehensive **management strategy**
- Florida citrus industry has not recovered and is in jeopardy at this time

Other examples of recent & significant emerging plant pathogens:

- A new wheat stem rust, *Puccinia graminis* Ug99, emerging in Africa (1998-99)
  - Had unique virulence factors
  - US wheat was highly susceptible; significant grower concerns
  - Experts warned that it **could kill more than 80% of the world's wheat**
  - Fear of Ug99 caused **short-term price spikes** on world wheat markets
- *Cassava brown streak virus* threatens food security in Africa (2008-16)
  - **CBSD** is spreading in Africa, seriously threatening food security in unstable regions, such as Rwanda and Tanzania.

Image Credit: B. Khizza

National Academy of Sciences (2002): A **strong national security plan** should include

- Early detection and diagnostic systems
- Epidemiological models for predicting pathogen spread
- Reasonable but effective strategies and policies for crop biosecurity
- Distributed physical and administrative infrastructure
- National response coordination plan and infrastructure
- Strategies for forensic investigation and attribution in cases of intentional or criminal activity

Agricultural biosecurity: Agencies/entities having responsibility

- **USDA**
  - **Animal and Plant Health Inspection Service (USDA-APHIS)**
  - **National Plant Disease Recovery System (USDA-ARS)**
  - **National Plant Diagnostic Network (USDA- NIFA)**
  - **Grants Programs fund research addressing urgent agricultural issues**
- **Department of Homeland Security – Research, NBFAC**
- **Department of Justice – FBI**

Image credits: USDA ARS

Food security is in the hands of farmers… and scientists.

Image Credit: Carl Wycoff/Flikr