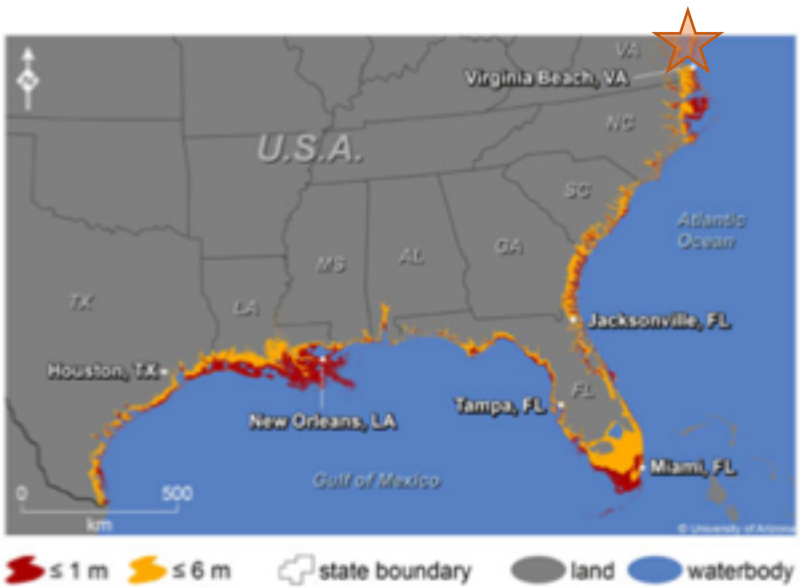
Before teaching at Virginia Tech I worked for Crowder Construction and assisted FEMA during super storm Sandy.

CROWDER CONSTRUCTION COMPANY

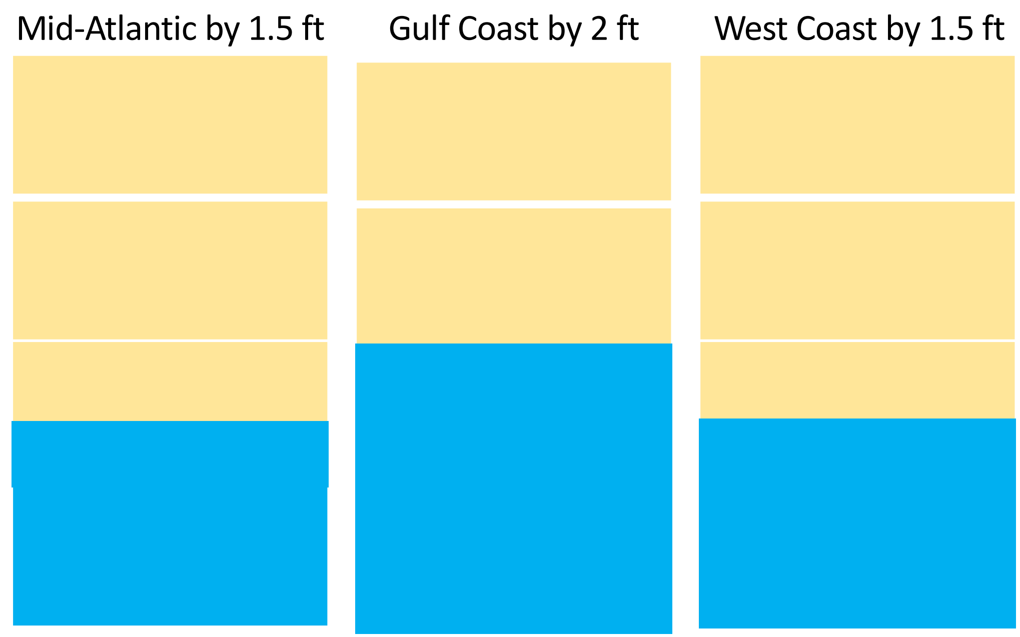
FEMA

Not only are more severe storms expected to continue but sea level in is expected to rise between 1 and 3+ feet by as early as 2060

(World Resources Institute 2014).



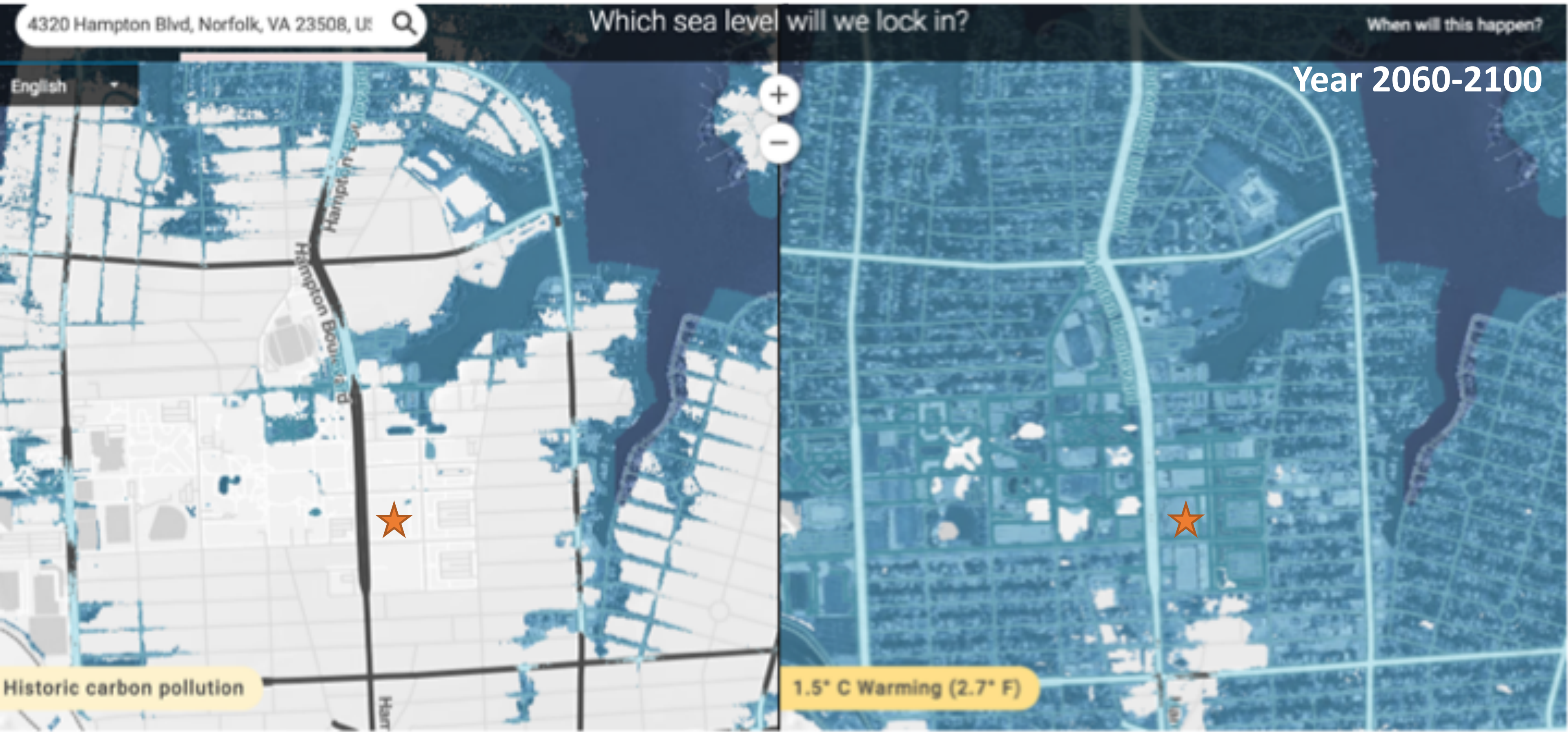
By 2060 sea level is expected to rise 1.5-2ft



The Virginia Institute of Marine Science (VIMS) recurrent flooding study for Hampton Roads Virginia found a 1.5-foot rise in sea level and a 3-foot storm surge

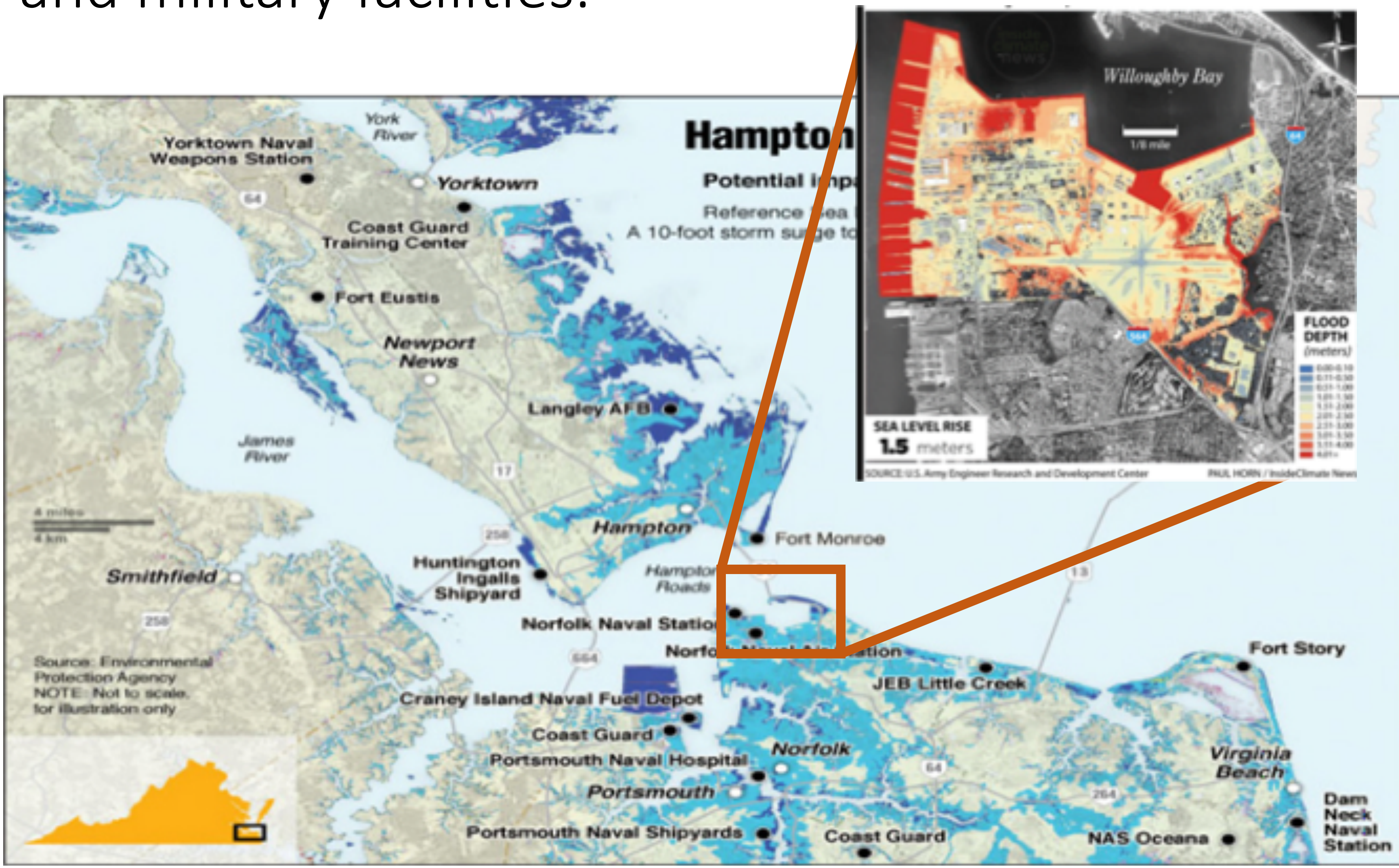
(Intergovernmental Pilot Project 2016).

Based on *Proceedings of the National Academy of Science and* NOAA forecasts, without any interventions the TED Constant Center will be under water in nearly 4 decades.

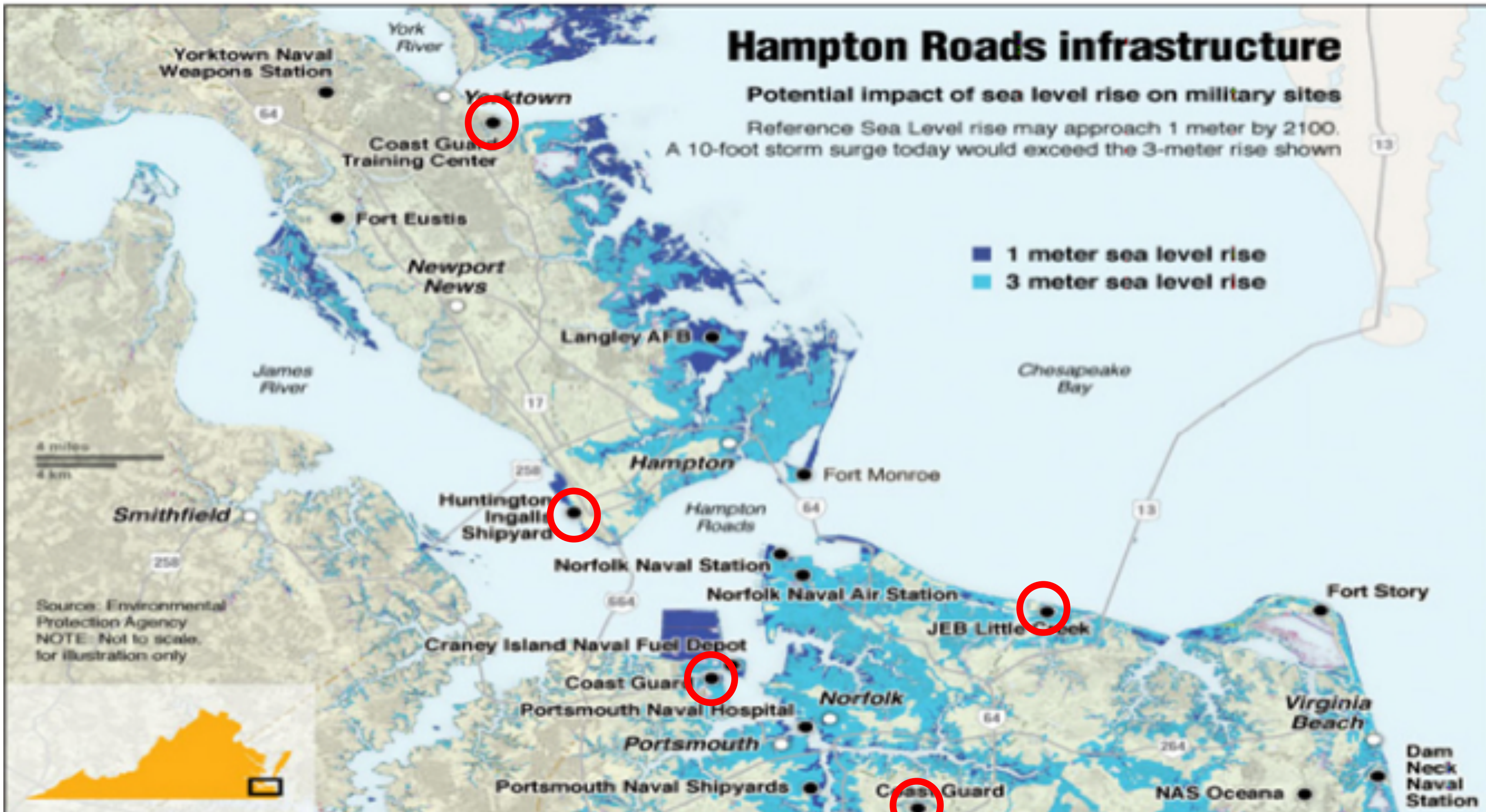


https://choices.climatecentral.org/#14/38.8680/-77.0497?compare=temperatures&carbon-end-yr=2100&scenario-a=warming-4&scenario-b=warming-2

While private property is at threat so are government and military facilities.



US Coast Guard is most vulnerable due to number and proximity of bases close to the sea.



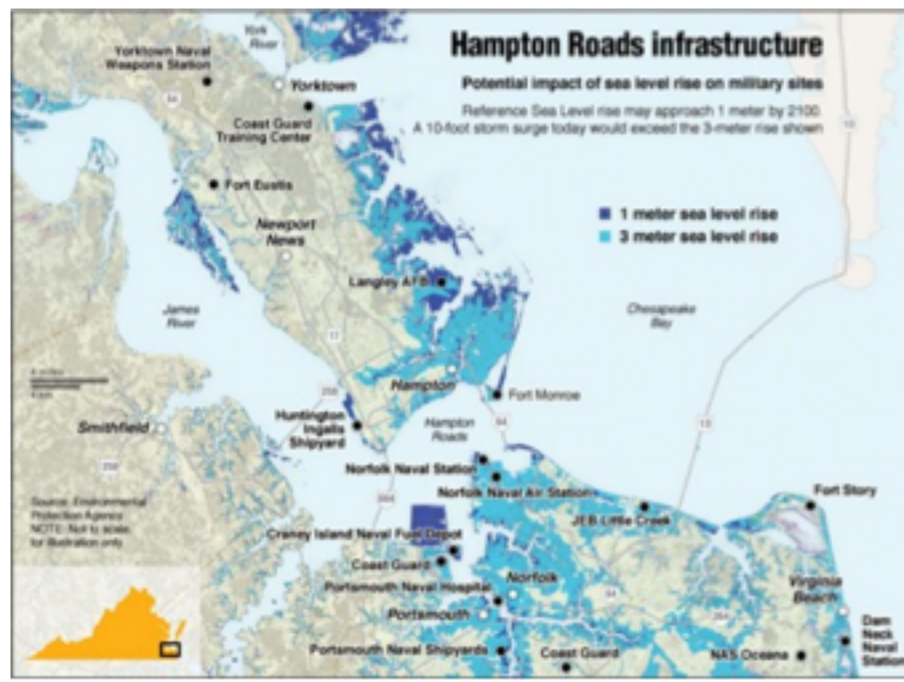
This is a problem because Coast Guard, and others are the first responders during natural disaster events. Disruptions can lead to delayed response.

Hurricane Harvey, 2017

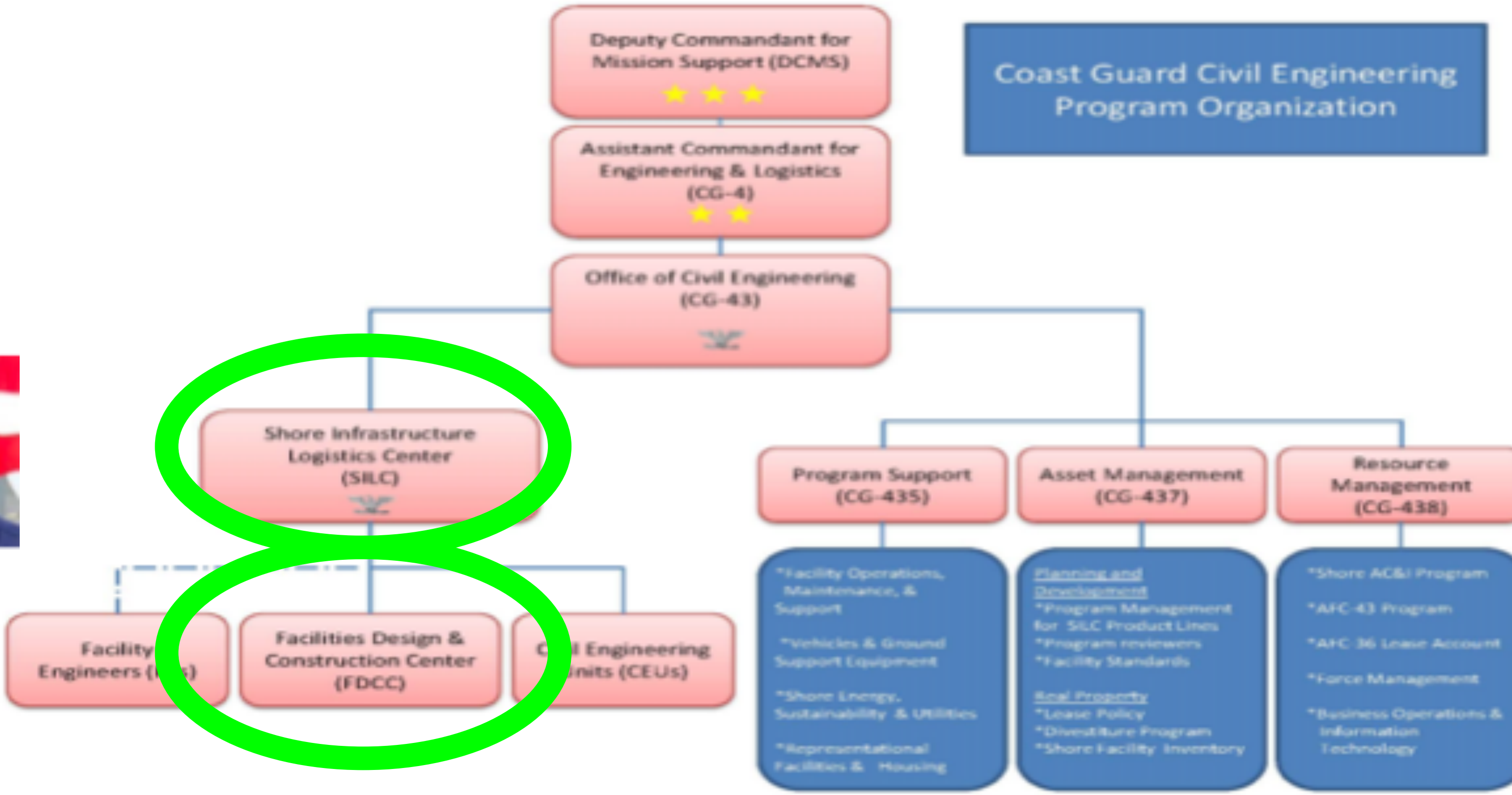
Coast Guardsmen used Google Docs to keep track of incoming phone calls, due to outages on base.

How is the Coast Guard preparing facilities for the effects of sea level rise? And what more can we do about it?

1. Interviews with Coast Guard civil engineers in Hampton Roads
2. Case studies of renovations to Coast Guard bases
3. Review identified barriers to more resilient design
4. Possible solutions



We used a mix methods approach of interviews and content analysis to understand how the Coast Guard in Hampton Roads is preparing for sea level rise.



Source: Civil Engineering Manual COMDTINST M11000.11B

To confirm the interview response, 20 facilities maintenance projects were chosen from the Coast Guard database at random, 17 were used.

Natural disaster	Number of cases
Wind	7
Flood	10
Total	17

The projects range in cost from $575,000 to $5.5 million and all occurred between 2014 - 2016.

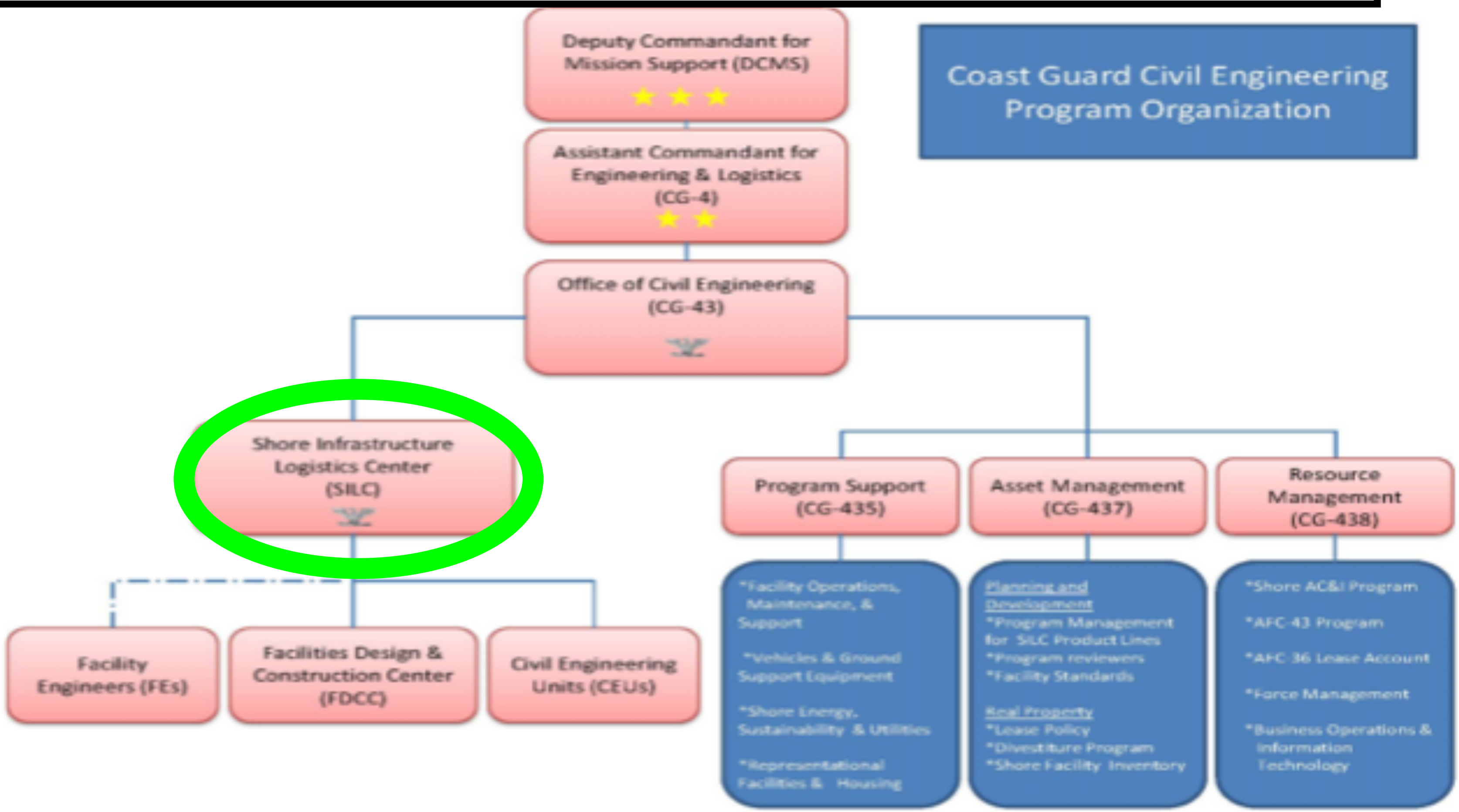
Shore Infrastructure Logistics Center (SILC)

What is being done day to day to account for sea level rise?

- *"Nothing, mostly fixing broken things"*

Is there any maintenance being done to adapt to sea level rise?

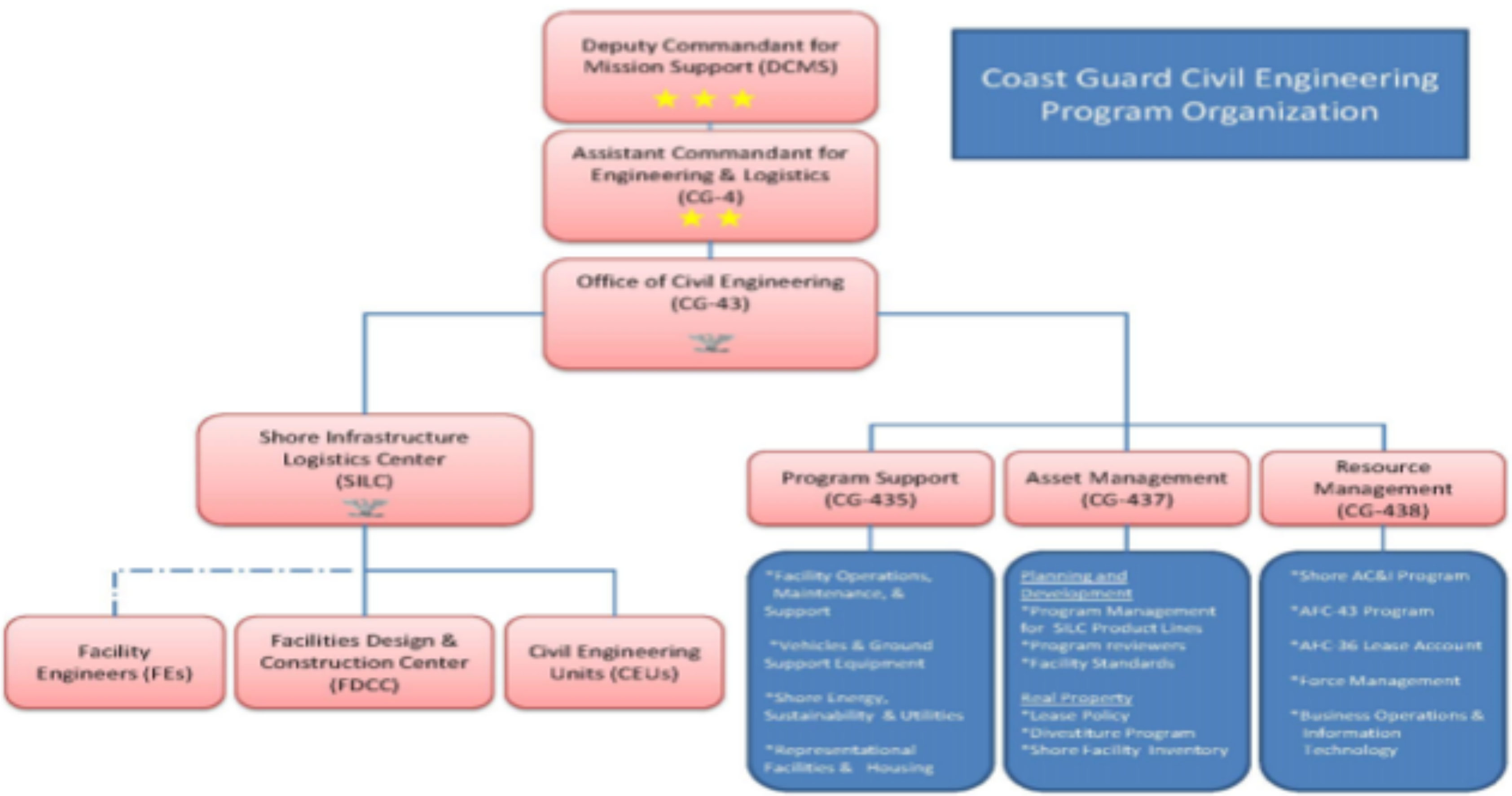
- *"SLR/resiliency isn't really a big deal until after a storm hits."*
- *"Resiliency work is a side project, collateral duty. Not a primary job."*



<u>Facility Design and Constructions Center (FD&CC)</u>

Can you describe the additional job duties that climate change will entail for you?

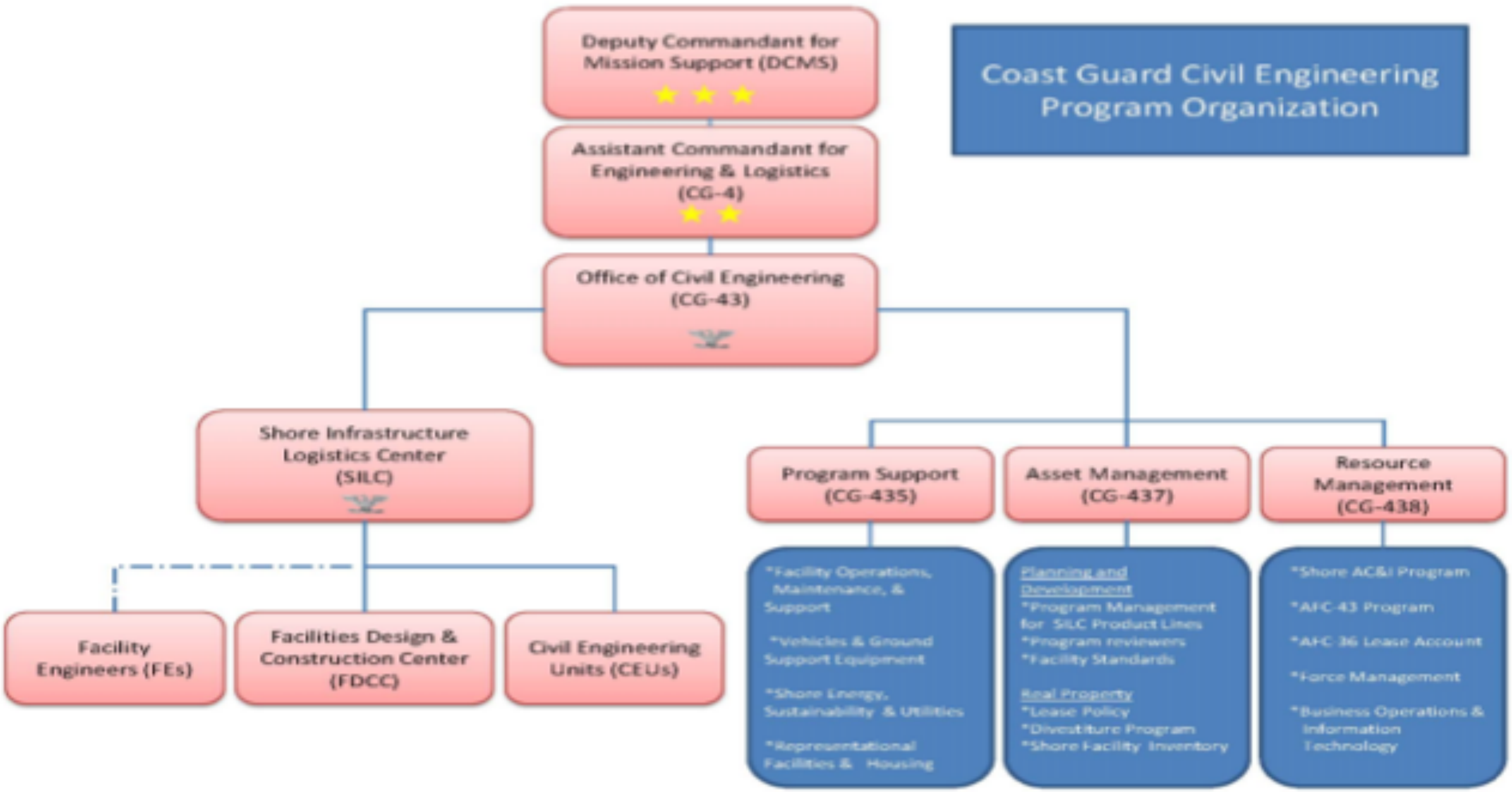
- *"The impacts of sea level rise needs to be addressed corporately."*
- *"Coast Guard fails to consider these issues at the highest levels."*



Facility Design and Constructions Center (FD&CC)

Can you describe the design process to account for natural disasters:

- *"We only consider what is in federal, state, and local design codes."*
- *"I am hesitant to design above code because it will be seen as over-designing and possibly seen as wasteful spending"*



Out of the 17 projects only two included above code recommendations to protect against flooding.

Natural disaster event	Number of cases	Resiliency options presented	Cases that selected the resilient construction option
Wind	7	0	0
Flood	10	2	2
Total	17	2	2

The two maintenance projects that met resilience options were due to previous damage.

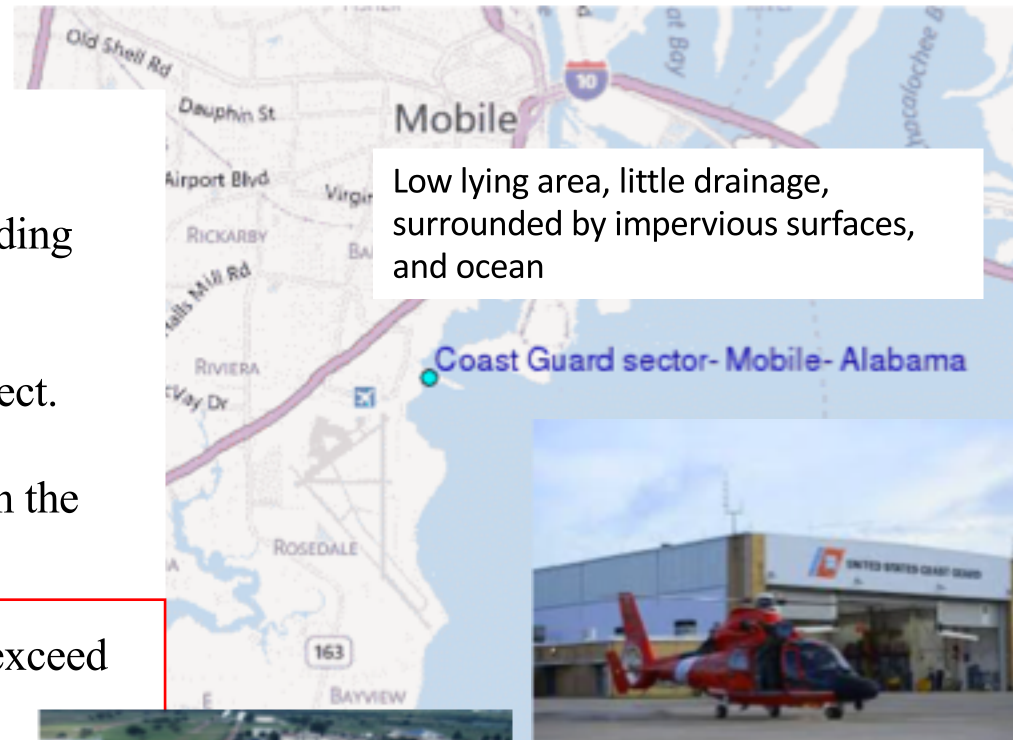
Station Base Mobile, AL

Storm Sewer was undersized leading to flooding during 10-year storm events.

Two alternatives were proposed for this project.

Alternative #1: Replace the storm sewer with the same size piping

Alterative #2: Triple the sizing of piping to exceed 100 year rain fall event



Low lying area, little drainage, surrounded by impervious surfaces, and ocean

The two maintenance projects that met resilience options were due to previous damage.

Station Brant Point, Nantucket, MA

Station suffered continue flooding events causing shortages in electrical and mechanical systems

Two alternatives proposed:

Alternative #1: Maintenance repairs, “helpful” but would not solve the flooding problem. The electrical and mechanical systems below flood elevation would continue to be subject to expensive flood damage

Alternative #2: The flood zone currently is above the location where the critical electrical and mechanical systems are placed.

The additional 15 projects did not include a resilience alternative.

Station Base Los Angeles, CA

Dock mooring facilities reaching end of useful life.

Cost: $694K

Two alternatives proposed:

Alterative #1: Do nothing - allow bulkhead wall to deteriorate, to the point where it needs to be replaced.

Alternative #2: Conduct maintenance prescribed in project scope (preferred alternative)

No additional recommendations were made to prepare the facility for change in sea level rise, more severe storms.

The additional 15 projects did not include a resilience alternative.

Station Base San Francisco, CA

Heavy rains caused landslide into an existing building on the base. Damage occurred to the building and was deemed unsafe for operation.

Cost: $575K

No alternatives provided: Repair barrier wall and add netting and anchorages.

No additional recommendations were made to prepare the facility for change in sea level rise, more severe storms, or rain events.

The additional 15 projects did not include a resilience alternative.

Station Base Cape May, NJ

Demolishing 2 existing HVAC systems and installing new system. Current HVAC system are causing mold and poor indoor air quality.

Cost: $1.7 Million

Three alternatives provided:

Alternative #1: New HVAC system

Alterative #2: Mold remediation

Alternative #3: Do nothing

Based on documents: sea level rise, increased heat, flooding events, etc. were not considered when designing location of HVAC system, vents, etc.

The two maintenance projects that met resilience options were due to previous damage.

<u>Station Brant Point, Nantucket, MA</u>

Station suffered continue flooding events causing shortages in electrical and mechanical systems

Cost: $1.8 Million

Two alternatives proposed:

<u>Alternative #1</u>: Maintenance repairs to electrical and mechanical systems below flood elevation but would continue to be subject to expensive flood damage.

<u>Alternative #2:</u> The flood zone currently is above the location where the critical electrical and mechanical systems are placed. Move systems above flood zone.

- “More cost-effective strategy is to react once a natural disaster occurs instead of spending scare resources upfront.”

- “New construction, planning phases are in place but maintenance projects are not subjected to the same requirements.”

- “The lack of resilience planning is a function of the process. Immediate concerns are addressed as quickly as possible.”

- “It is easier for Coast Guard engineers to justify longer, more expensive maintenance projects that incorporate resiliency when the effects of climate change are already being felt.”

Previous research aligns with out findings. Coast Guard prepares for the effects of sea level rise during reconstruction of damaged facilities.

Coast Guard Station Gulfport after Katrina was rebuilt to withstand a category four hurricane ($17 million)

- Out of 15 rebuilt facilities none went above code for wind design
- 5 Out of 15 built above FEMA 100 year flood elevation

(Healy et al., 2016)


Kissam Ave
©2014 Google


TRIBUILT
APARO'S

How do we change from building back stronger to preparing during regular maintenance?


$700,000 replacing pier facilities


$575,000 replacing rock catchment


$1.7M to replace HVAC

Future Research:
What would the cost have been to include resilience upgrades at the time of maintenance?
What is the effect of requiring a maintenance alternative? Do not have to do it but have to provide one as an option.

How do we change from building back stronger to preparing during regular maintenance?

Current Building Practice

Super Storm Sandy

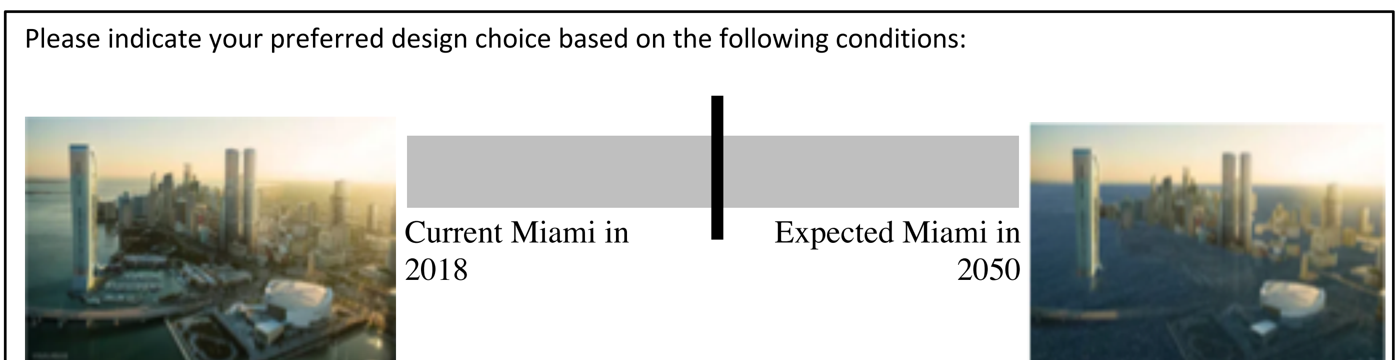
More Resilient

Challenges are not just engineering but behavioral:

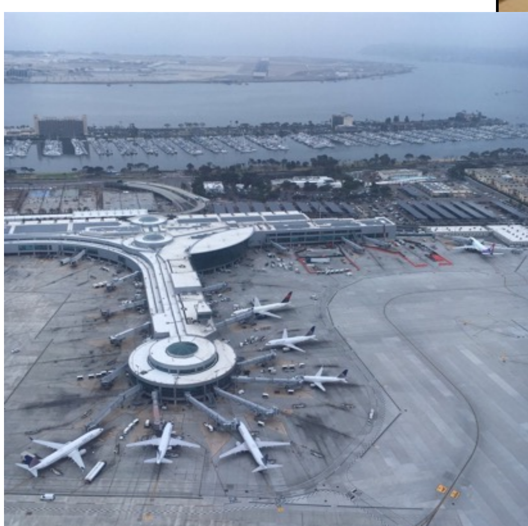
- Temporal discounting
- Uncertainty
- Inertia/Status Quo
- Awareness

Temporal discounting: prefer $100 today instead of $120 a month from now.

- Temporal discounting contributes to
  - *obesity epidemic* (Barlow et al 2016),
  - *bankruptcies* from balloon mortgages (Hershfield et al, 2012),
  - widespread *insufficient retirement savings* (Feigenbaum et al, 2015)



20 graduate engineering students received either the vivid images of today or the future.



Envision is 60 credits, 5 categories.

QUALITY OF LIFE
13 Credits

QL3.1 Preserve Historic & Cultural Resources
QL3.2 Preserve Views & Local Character
QL3.3 Enhance Public Space

QL0.0 Innovate or Exceed Credit Requirements

LEADERSHIP
10 Credits

1 COLLABORATION
LD1.1 Provide Effective Leadership & Commitment
LD1.2 Establish A Sustainability Management System
LD1.3 Foster Collaboration & Teamwork
LD1.4 Provide for Stakeholder Involvement

2 MANAGEMENT
LD2.1 Pursue By-Product Synergy Opportunities
LD2.2 Improve Infrastructure Integration

3 PLANNING
LD3.1 Plan For Long-Term Monitoring & Maintenance
LD3.2 Address Conflicting Regulations & Policies
LD3.3 Extend Useful Life

LD0.0 Innovate or Exceed Credit Requirements

RESOURCE ALLOCATION
14 Credits

1 MATERIALS
RA1.1 Reduce Net Embodied Energy
RA1.2 Support Sustainable Procurement Practices
RA1.3 Use Recycled Materials
RA1.4 Use Regional Materials
RA1.5 Divert Waste From Landfills
RA1.6 Reduce Excavated Materials Taken Off Site
RA1.7 Provide For Deconstruction & Recycling

2 ENERGY
RA2.1 Reduce Energy Consumption
RA2.2 Use Renewable Energy
RA2.3 Commission & Monitor Energy Systems

3 WATER
RA3.1 Protect Fresh Water Availability
RA3.2 Reduce Potable Water Consumption
RA3.3 Monitor Water Systems

RA0.0 Innovate or Exceed Credit Requirements

NATURAL WORLD
15 Credits

1 SITING
NW1.1 Preserve Prime Habitat
NW1.2 Protect Wetlands & Surface Water
NW1.3 Preserve Prime Farmland
NW1.4 Avoid Adverse Geology
NW1.5 Preserve Floodplain Functions
NW1.6 Avoid Unsuitable Development on Steep Slopes
NW1.7 Preserve Greenfields

2 LAND+WATER
NW2.1 Manage Stormwater
NW2.2 Reduce Pesticide & Fertilizer Impacts
NW2.3 Prevent Surface & Groundwater Contamination

3 BIODIVERSITY
NW3.1 Preserve Species Biodiversity
NW3.2 Control Invasive Species
NW3.3 Restore Disturbed Soils
NW3.4 Maintain Wetland & Surface Water Functions

NW0.0 Innovate or Exceed Credit Requirements

CLIMATE AND RISK
8 Credits

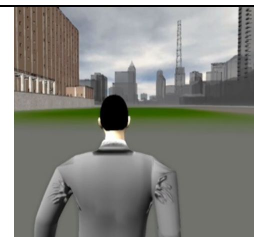
1 EMISSIONS
CR1.1 Reduce Greenhouse Gas Emissions
CR1.2 Reduce Air Pollutant Emissions

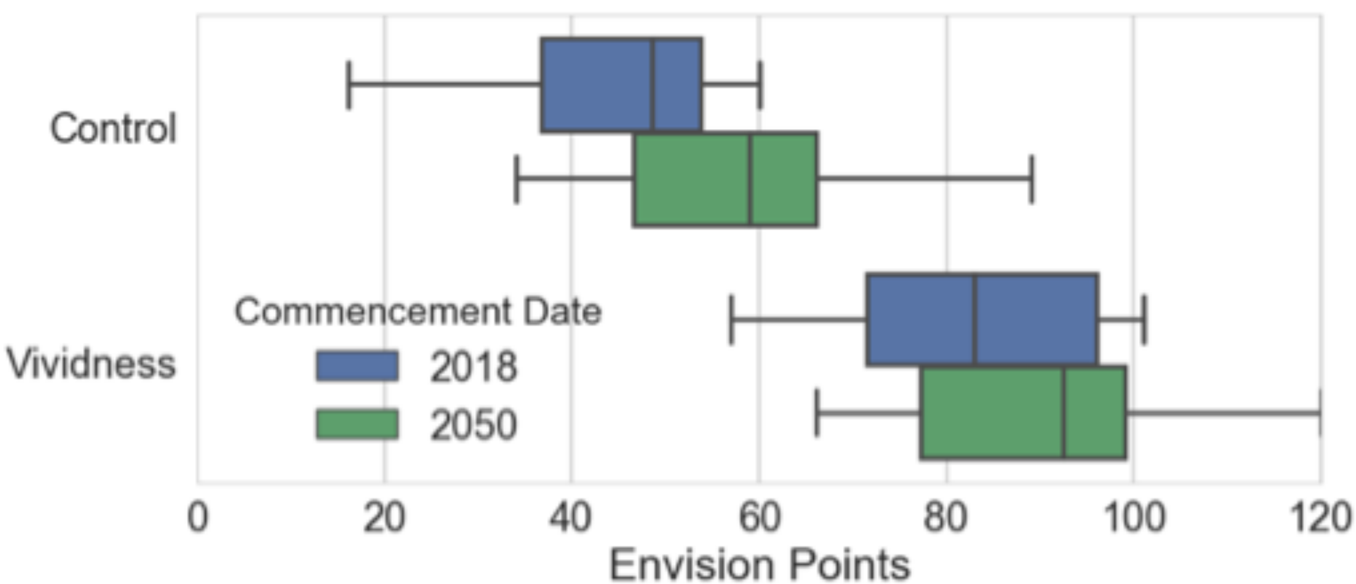
2 RESILIENCE
CR2.1 Assess Climate Threat
CR2.2 Avoid Traps & Vulnerabilities
CR2.3 Prepare For Long-Term Adaptability
CR2.4 Prepare For Short-Term Hazards
CR2.5 Manage Heat Island Effects

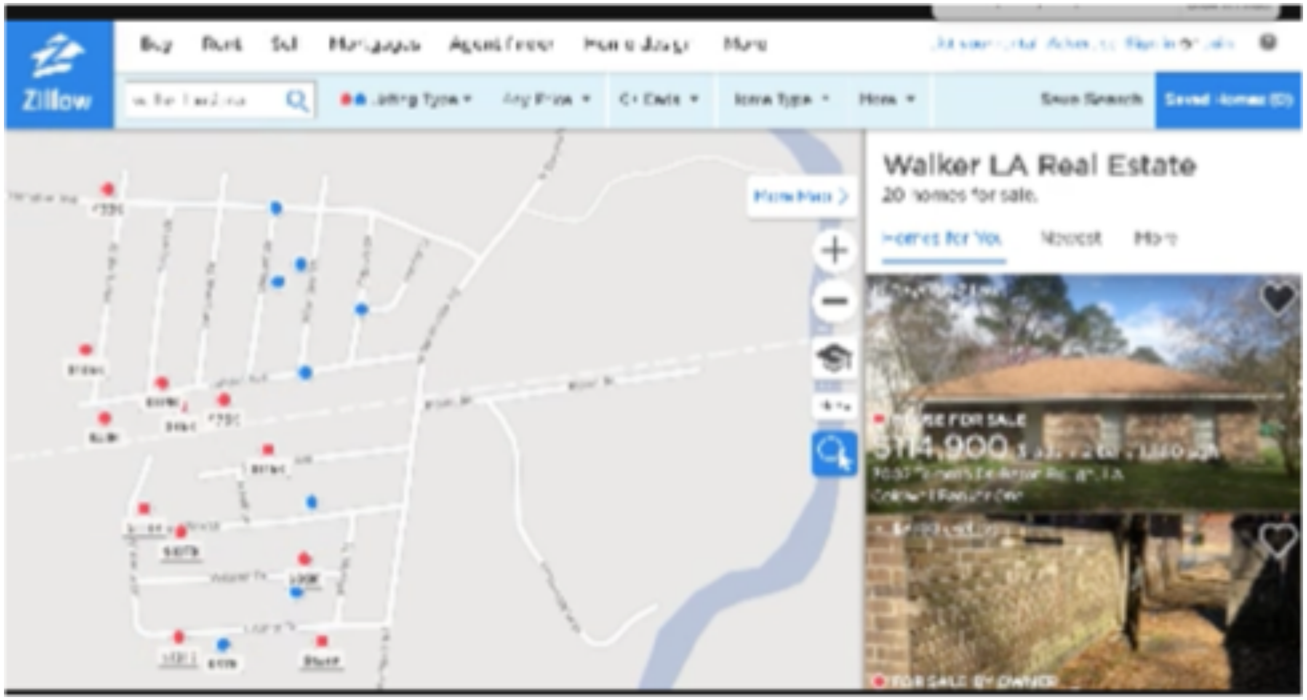
CR0.0 Innovate or Exceed Credit Requirement

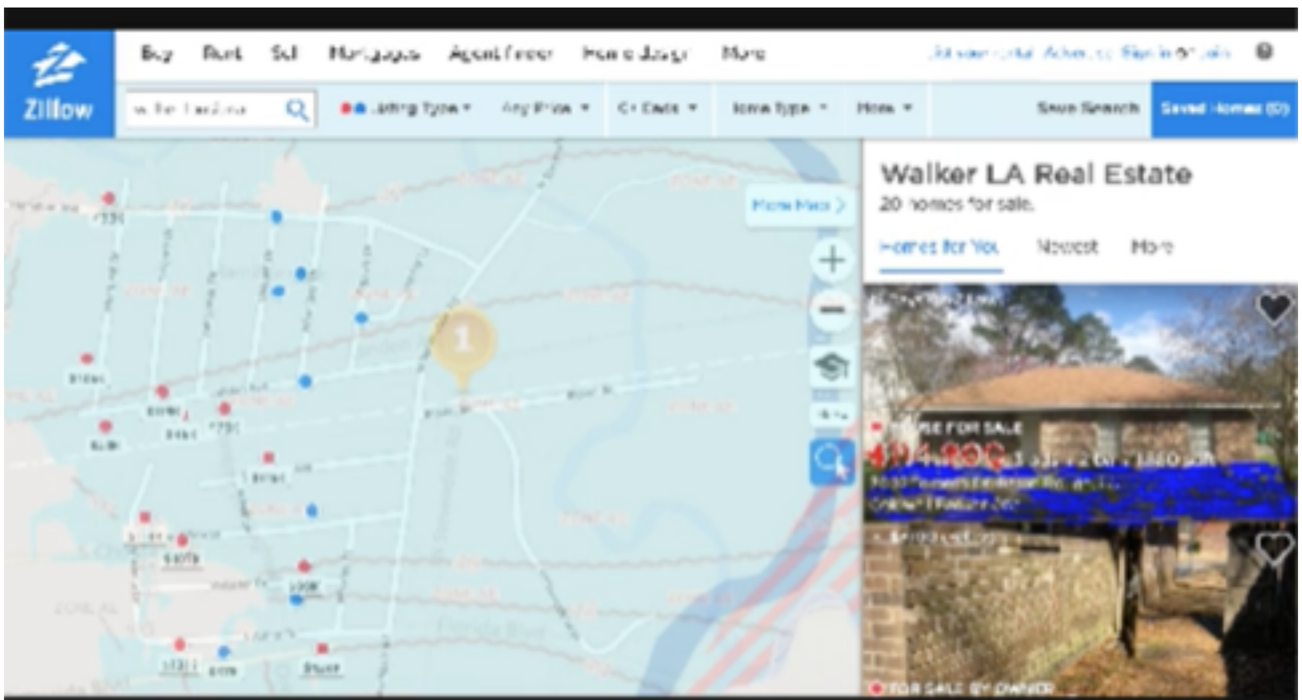
Vivid images of the future helped improve decision outcomes.

Envision Credits	Control (2018)	Vividness Intervention (2050)
Reduce greenhouse		17.3
Avoid traps and vul		11.6
Prepare for long ter		14.9
Prepare for short te		18.2
Maintain wetland a		6.8
Prepare for long ter		5.5
Extend useful life		9.1
Ave	[illegible]	**83.3**

Realism	*2D rendering*	*3D display*	*3D head mount*
2018			




Zillow
Walker LA Real Estate
20 homes for sale.


Zillow
Walker LA Real Estate
20 homes for sale.

Uncertainty and risk: lack of data for accurate probability or given standard deviation of probability

- To really know what a 100 year rain event is, you need at least have twice as many years of data – 200 for a 100 year event.
- 2,000 for a 1,000 year event projection.
- Modelers assume weather in the past is like the weather of today.
- The past and future resemble the present.

Use framing to change perspective of uncertainty

How we set up the choice, shapes behavior.

How we frame the information can change perspective.

- A 1% chance of flooding in a year (100year flood) is about a 26% chance of flooding during a 30 year mortgage.)
- A 0.2% chance of flooding (500 year flood) is a 6% chance of flooding during a 30 year mortgage.
- This is higher than the 4% risk of a structural fire in the house, but no one questions the need for fire insurance.

Inertia: Set better defaults

Default Choice:

organ donors

(Johnson and Goldstein, 2003).

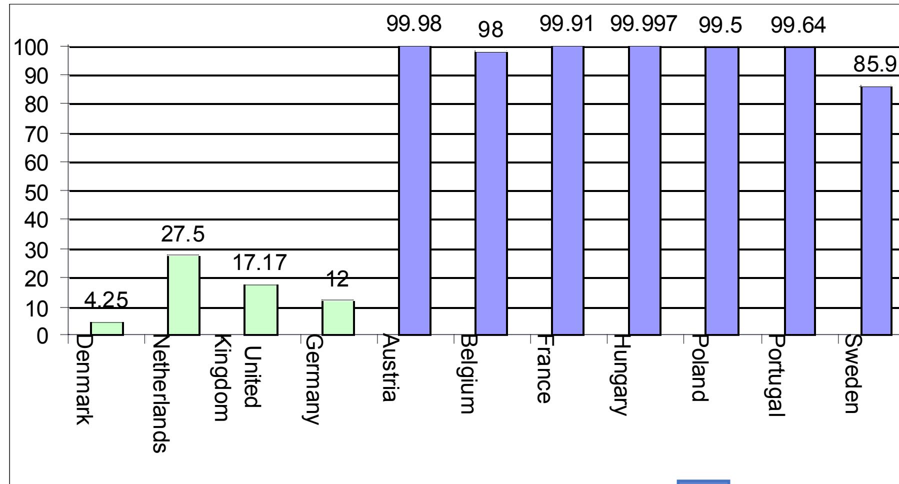
Opt-in

15% donor rate

Opt-out

93% donor rate

Changes perception of social norm.

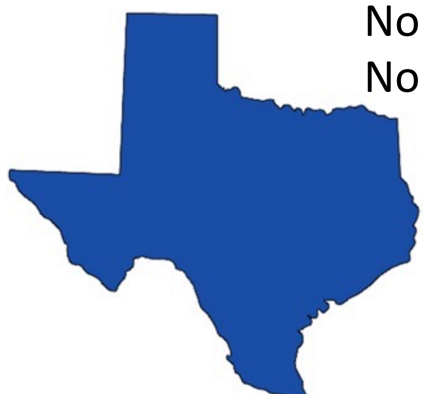


Opt-in or opt-out using statewide code:

(IBHS, 2013; Monte, 2012).

Opt-in

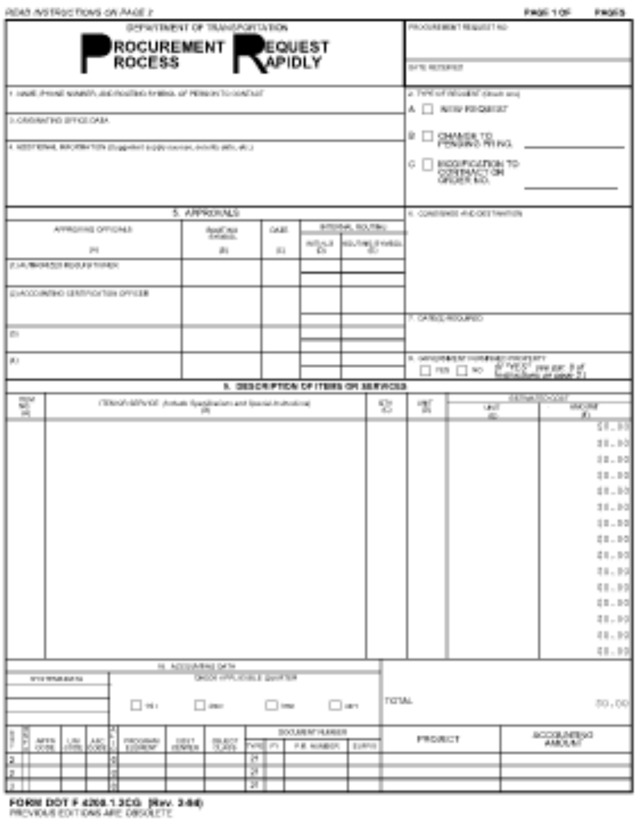
Opt-out

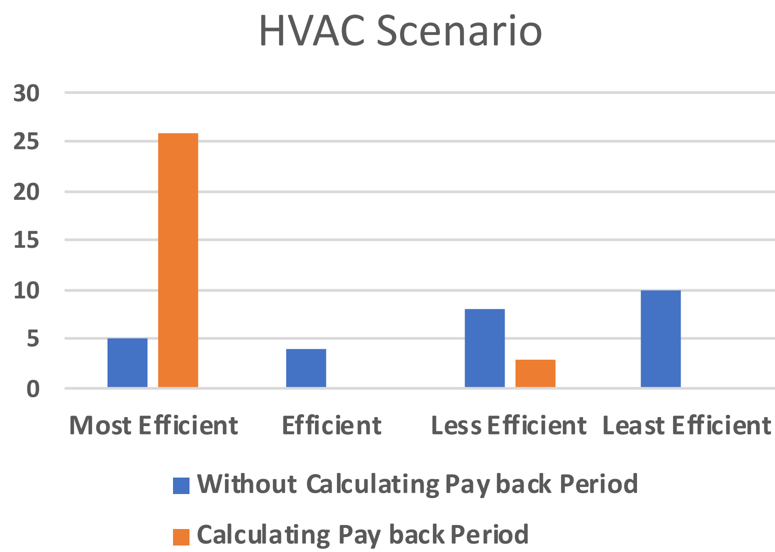


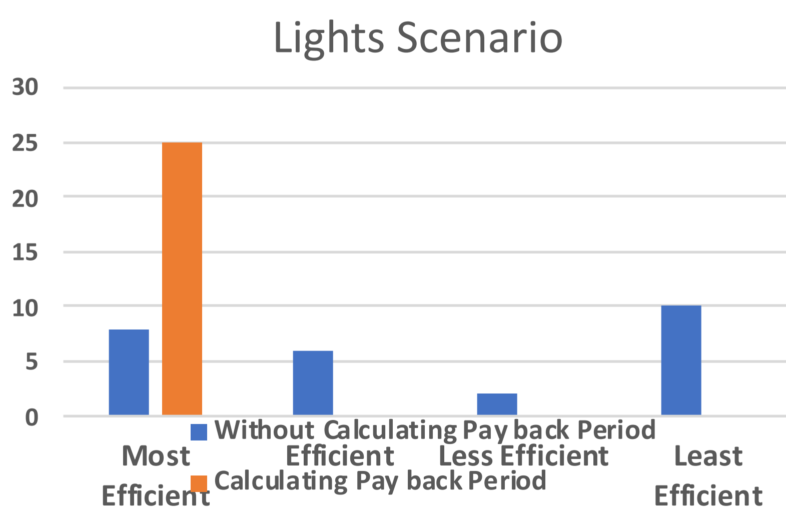
No Default = No Code

Default = Statewide code

Included a question on Coast Guard procurement form asking for pay back period.


DEPARTMENT OF TRANSPORTATION
PROCUREMENT REQUEST
PROCESS RAPIDLY
5. APPROVALS
DESCRIPTION OF ITEMS OR SERVICES
TOTAL
PROJECT





Maintenance is an opportunity to build in resilience, yet to frequently we are waiting for a disaster to occur.

$700,000 replacing pier facilities

$575,000 replacing rock catchment

$1.7M to replace HVAC

Current Building Practice

Super Storm Sandy

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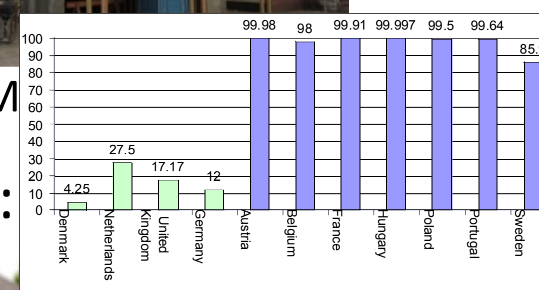

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- Inertia/Status Quo