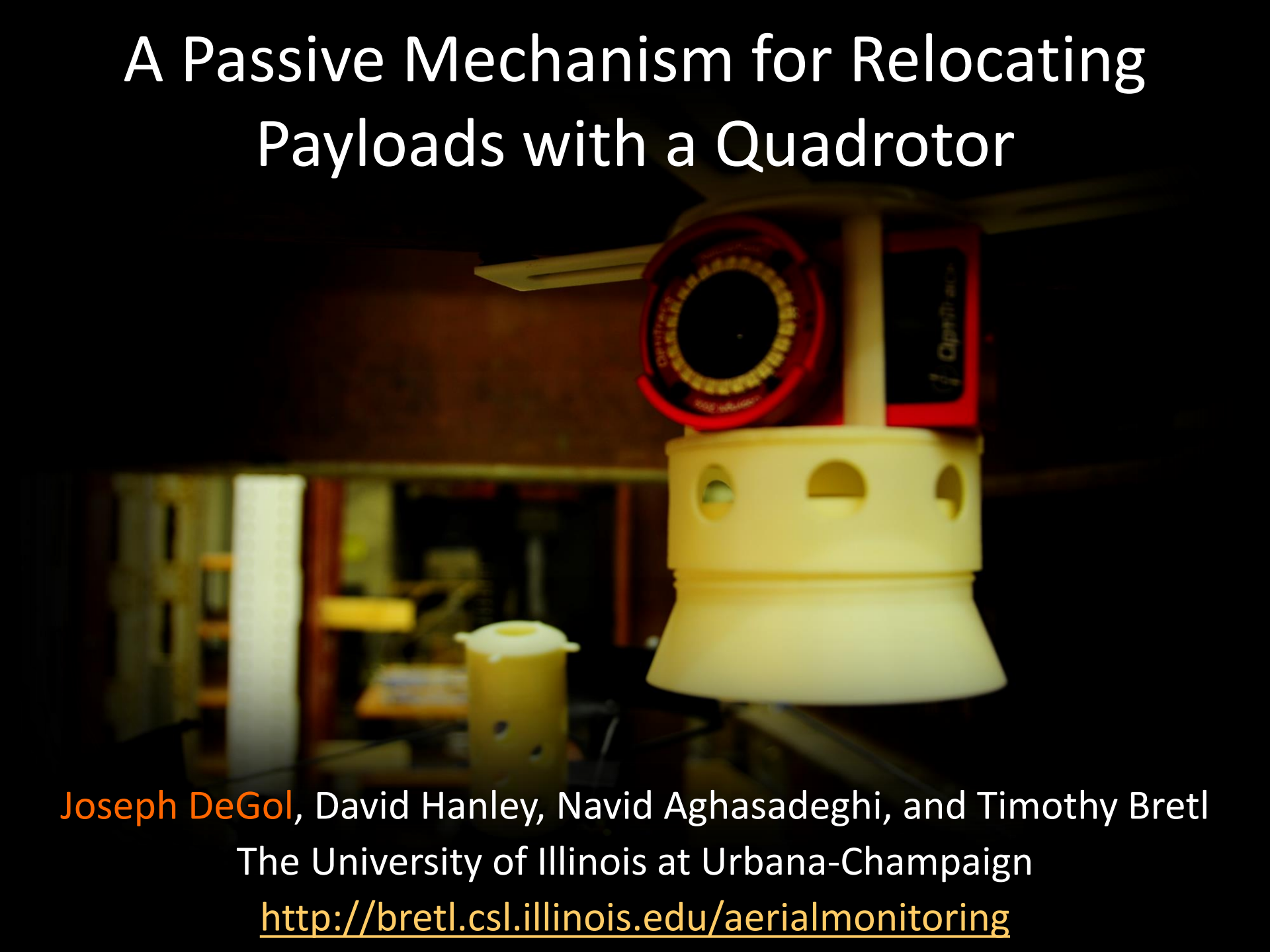
A Passive Mechanism for Relocating Payloads with a Quadrotor



Joseph DeGol, David Hanley, Navid Aghasadeghi, and Timothy Bretl
The University of Illinois at Urbana-Champaign
http://bretl.csl.illinois.edu/aerialmonitoring

Introduction

Construction is an important Industry

$1,064,594,000,000

Value of Construction Put in Place in the United States, 2015

*U.S. Census Bureau (2015)

+10-12 % Growth Rate

Commercial and industrial building sectors

* AIA Consensus Forecast (2015)

Investment will double in the next 15 years

By 2030, could be $13 trillion across energy, infrastructure, mining, and real-estate related projects.

* McKinesy and Company (2015)

Room for Improvement

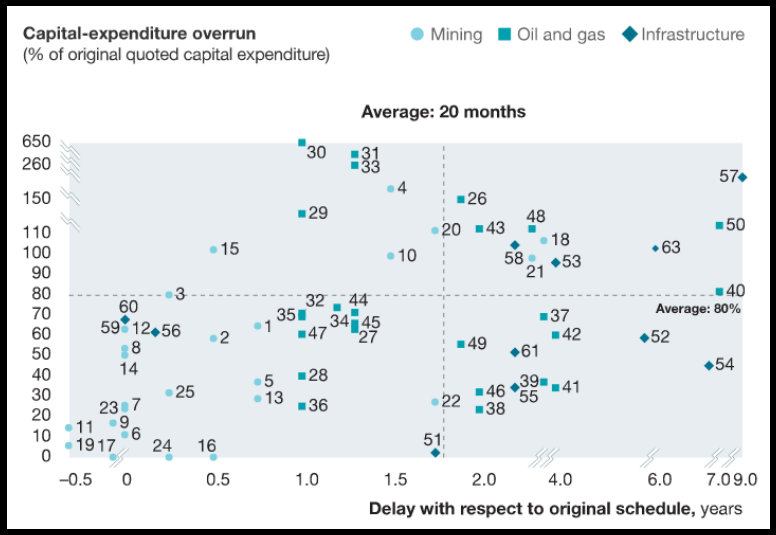
Safety:

197,800

Construction Site Injuries, 2013

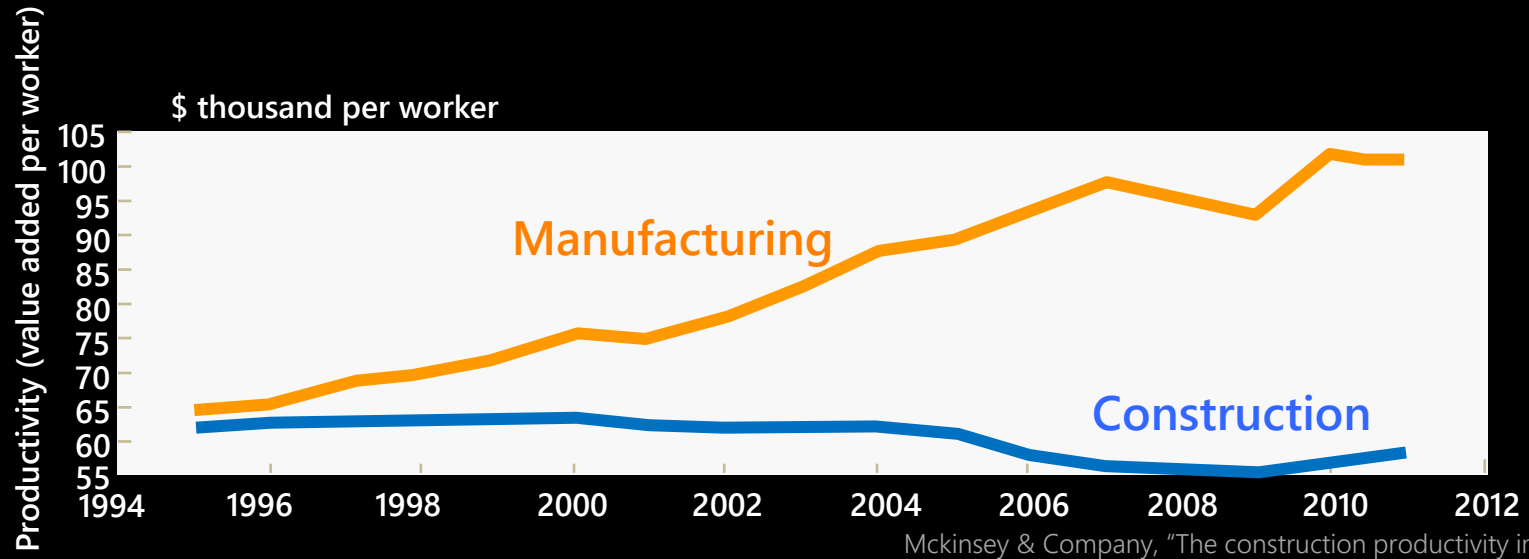
United Stated Department of Labor, Labor Statistics, 2013

Progress:



Mckinsey & Company 2015; based on public annual reports; HIS Herold Global Projects Database, data collected in Nov 2013

Productivity:

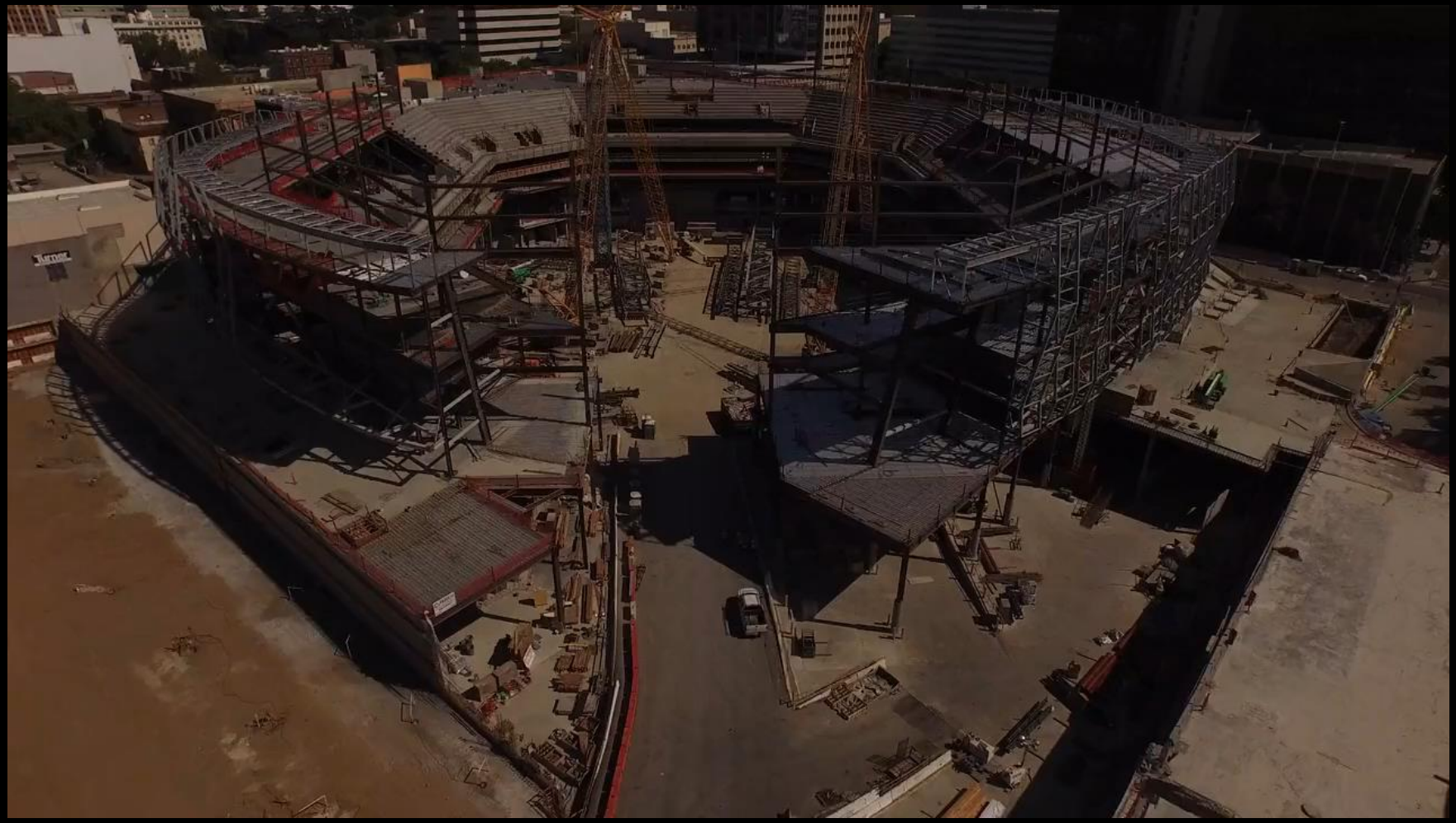


Mckinsey & Company, "The construction productivity imperative", 2015.

Nat'l Res. Counc. of the Nat'l Acad."Advancing the Competitiveness and Efficiency of the US Construction Industry." NAS, Washington, DC. 2009.

Bringing Robots to Construction Sites

To improve worker safety and productivity, monitor building progress, and track equipment and materials.



Sacramento King’s Stadium Project

Relocating Cameras on a Construction Site

1. Hovercraft have limited battery life
2. Construction Sites are always evolving.

A Passive Mechanism for Relocating Cameras

We are the first to make a passive mechanism for object relocation with a rotorcraft.

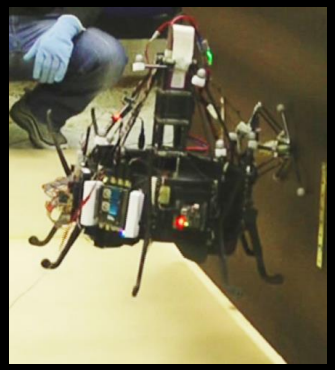
Passive

Doyle et. al.

Active

Mellinger et. al.

Thomas et. al.



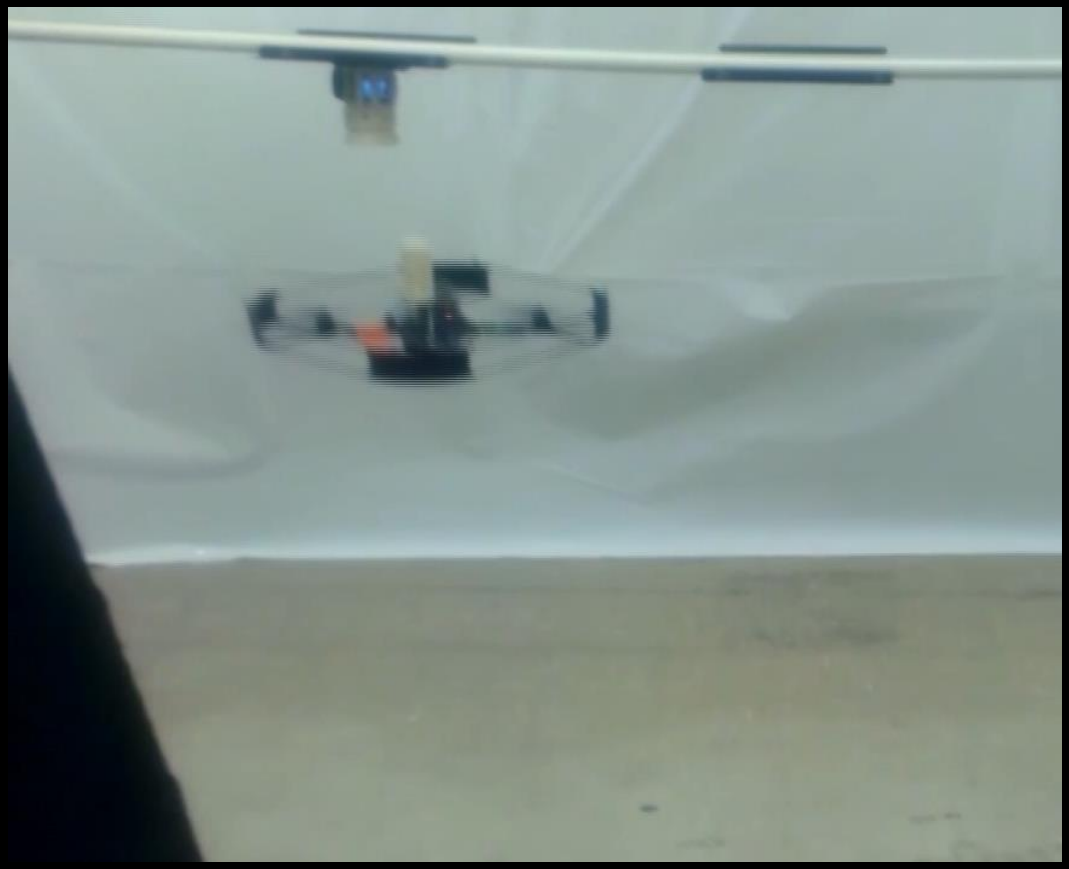
Keemink et. al.

Cano et. al.

Danko et. al.

A Passive Mechanism for Relocating Cameras

We are the first to make a passive mechanism for object relocation with a rotorcraft.



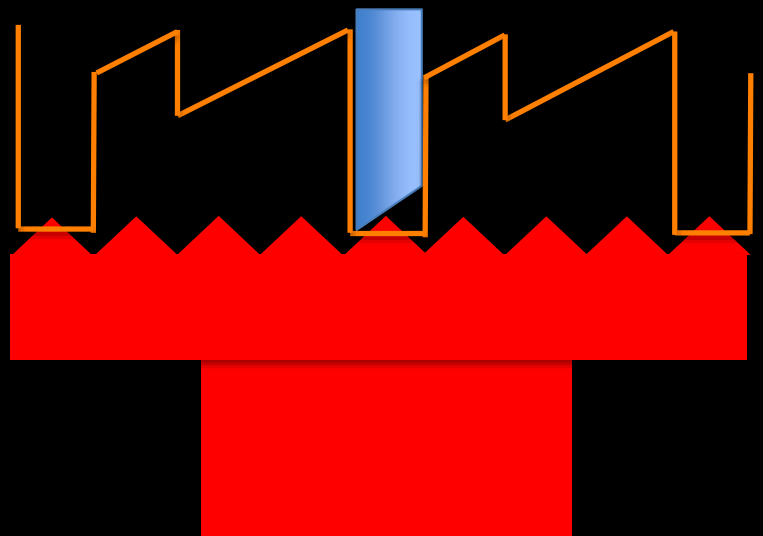
Our Passive Mechanism

The Cam Follower Mechanism in a Pen

Follower

Cam

Push Button



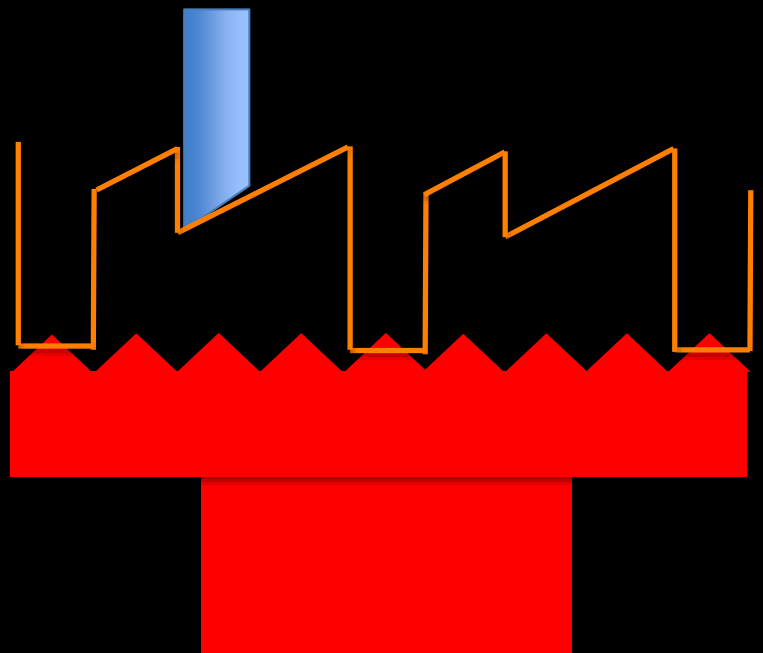
The Cam Follower Mechanism in a Pen

Pen Engaged

Follower

Cam

Push Button

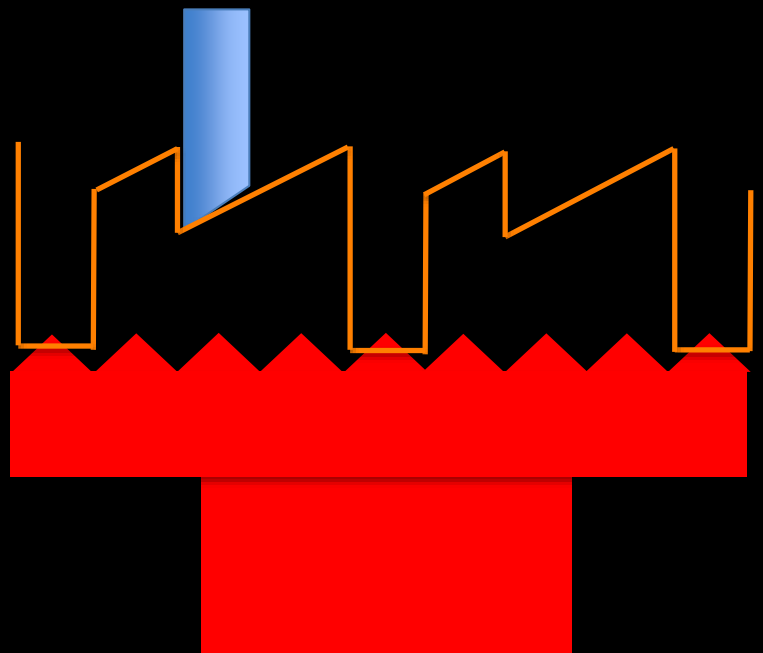


The Cam Follower Mechanism in a Pen

Follower

Cam

Push Button



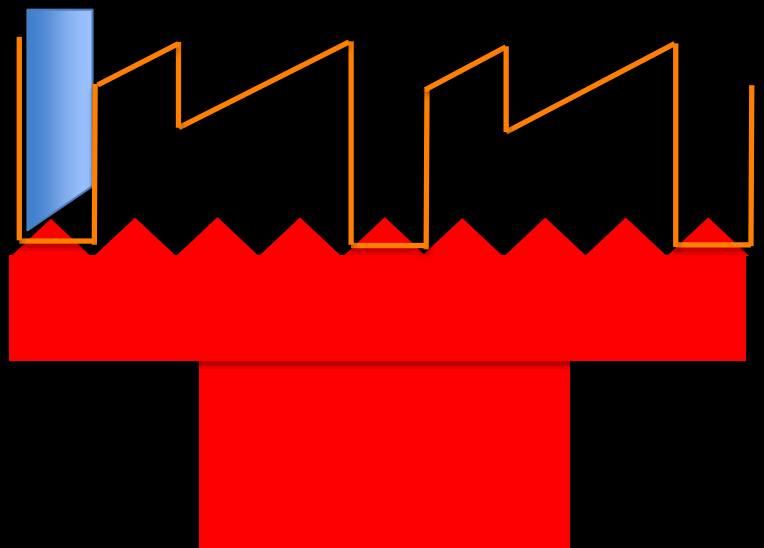
The Cam Follower Mechanism in a Pen

Pen Disengaged

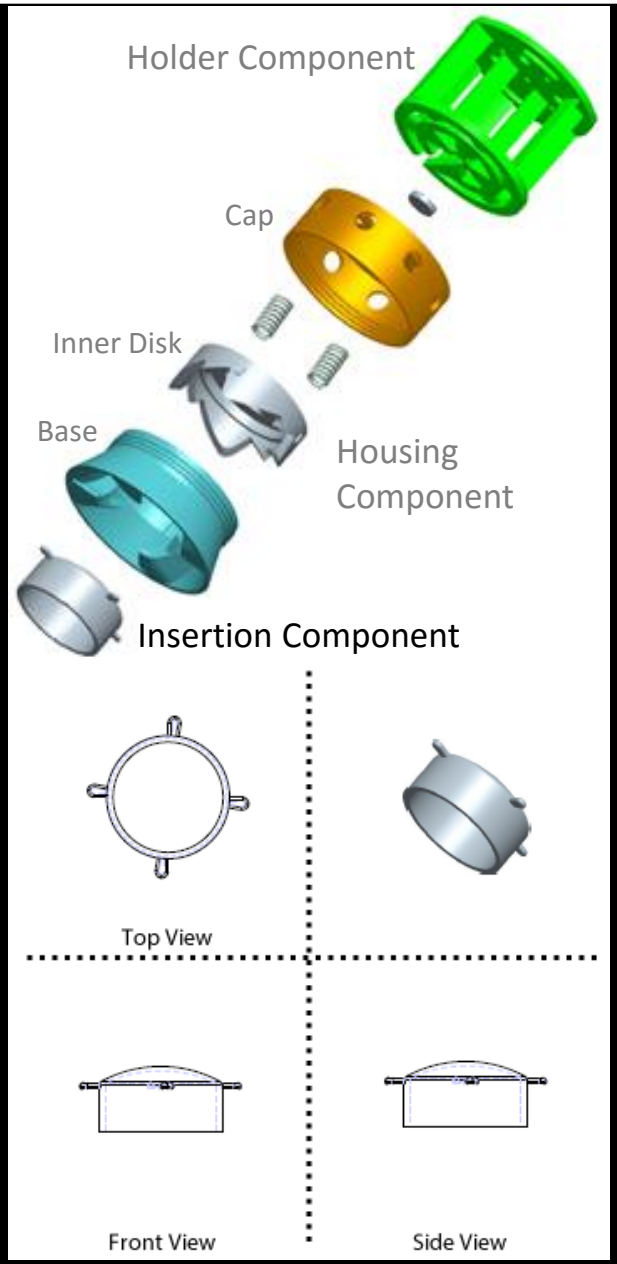
Follower

Cam

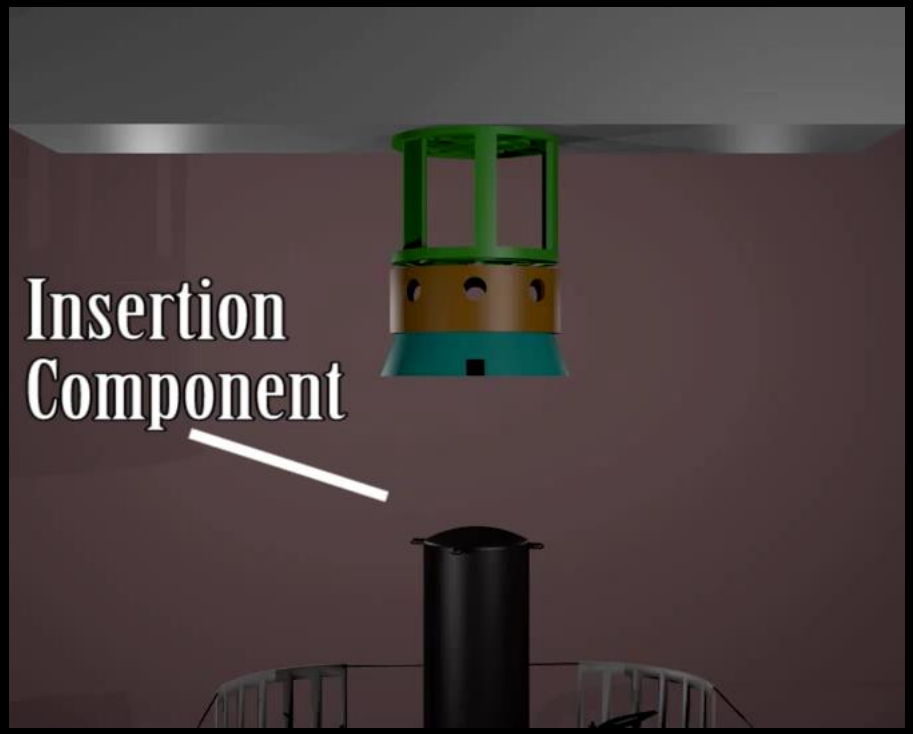
Push Button



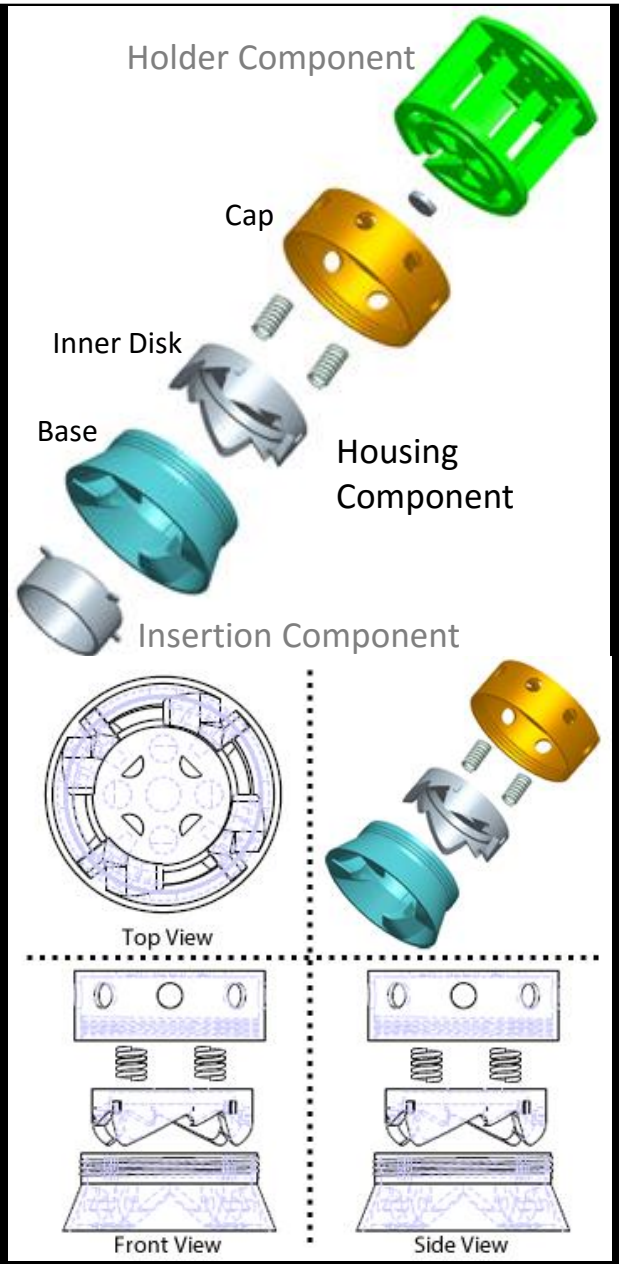
Mechanism Parts: Insertion Component



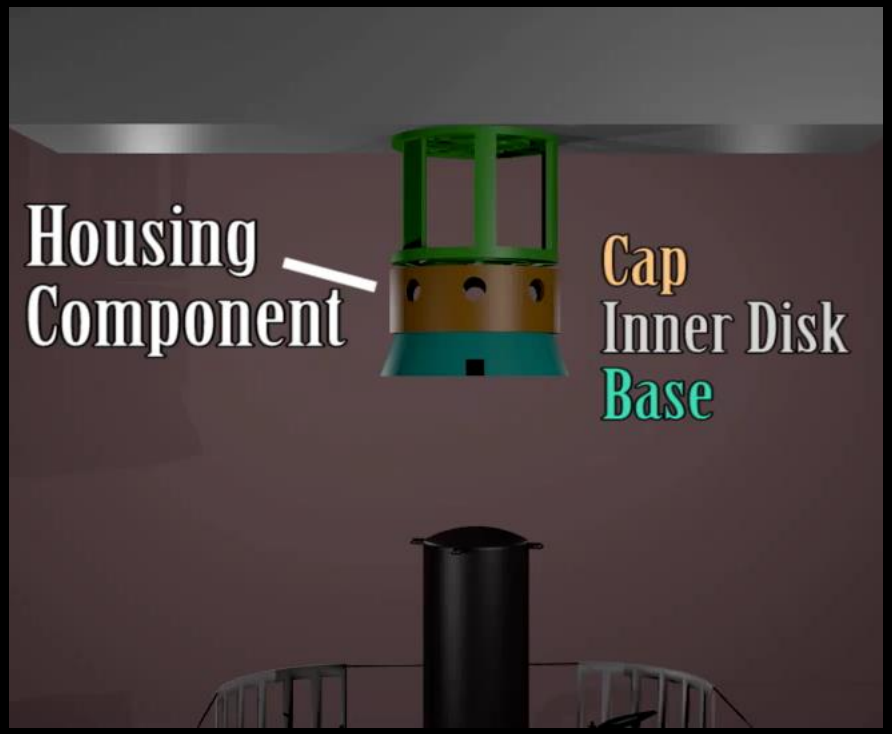
Analogous to the Follower



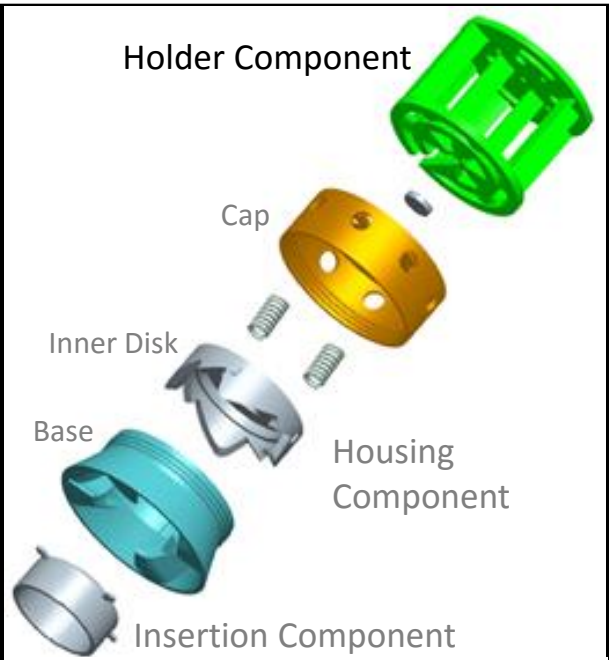
Mechanism Parts: Housing Component

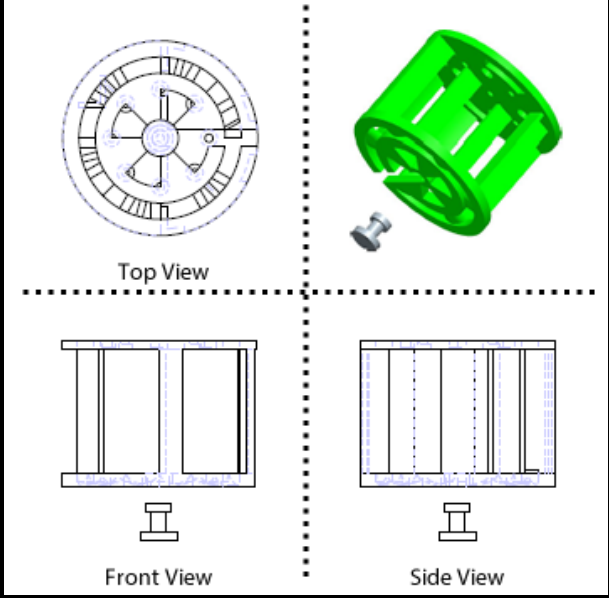


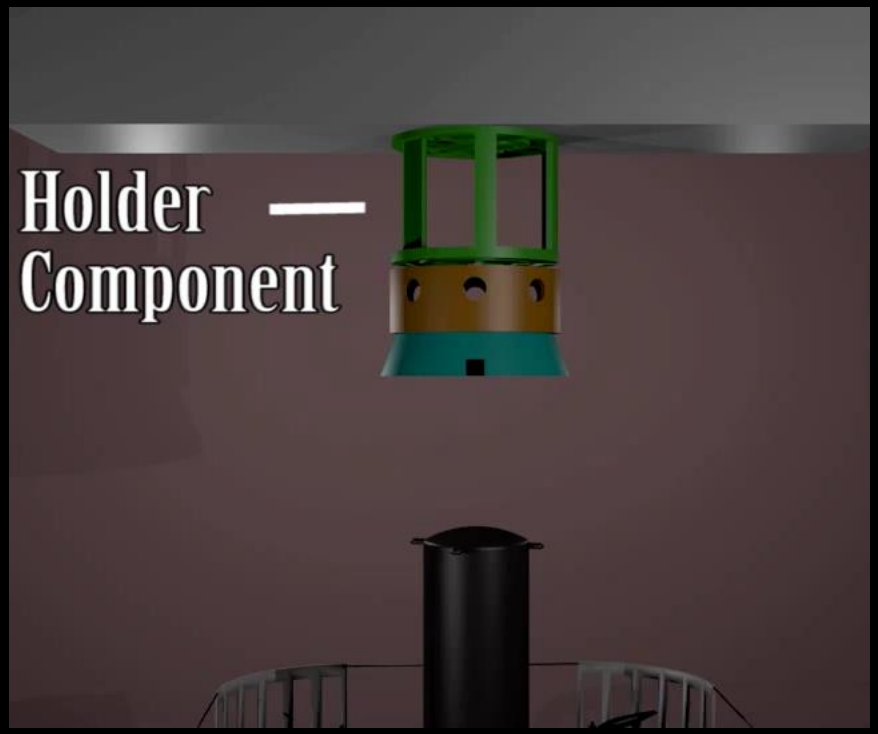
Analogous to the Cam and Pushbutton



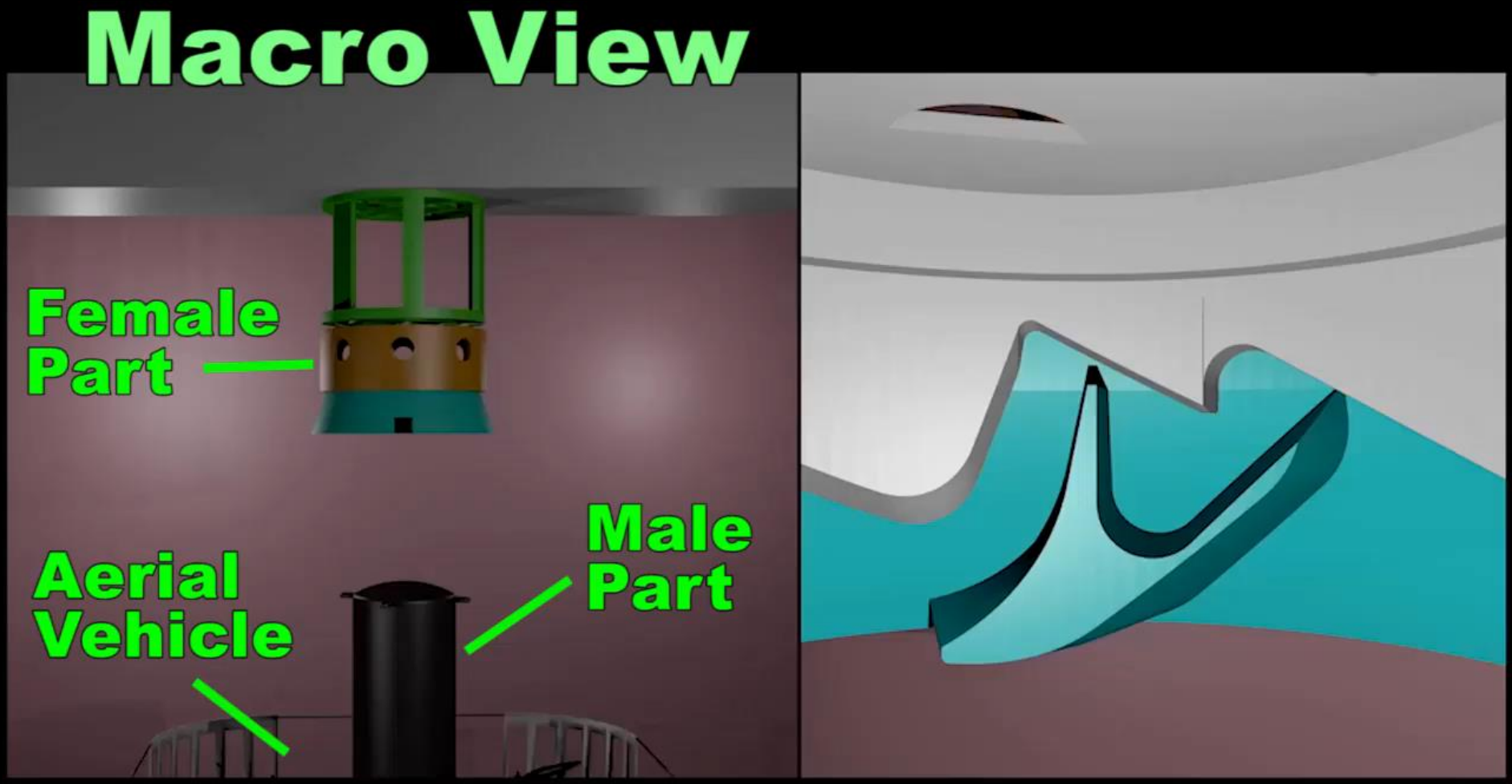
Mechanism Parts: Holder Component







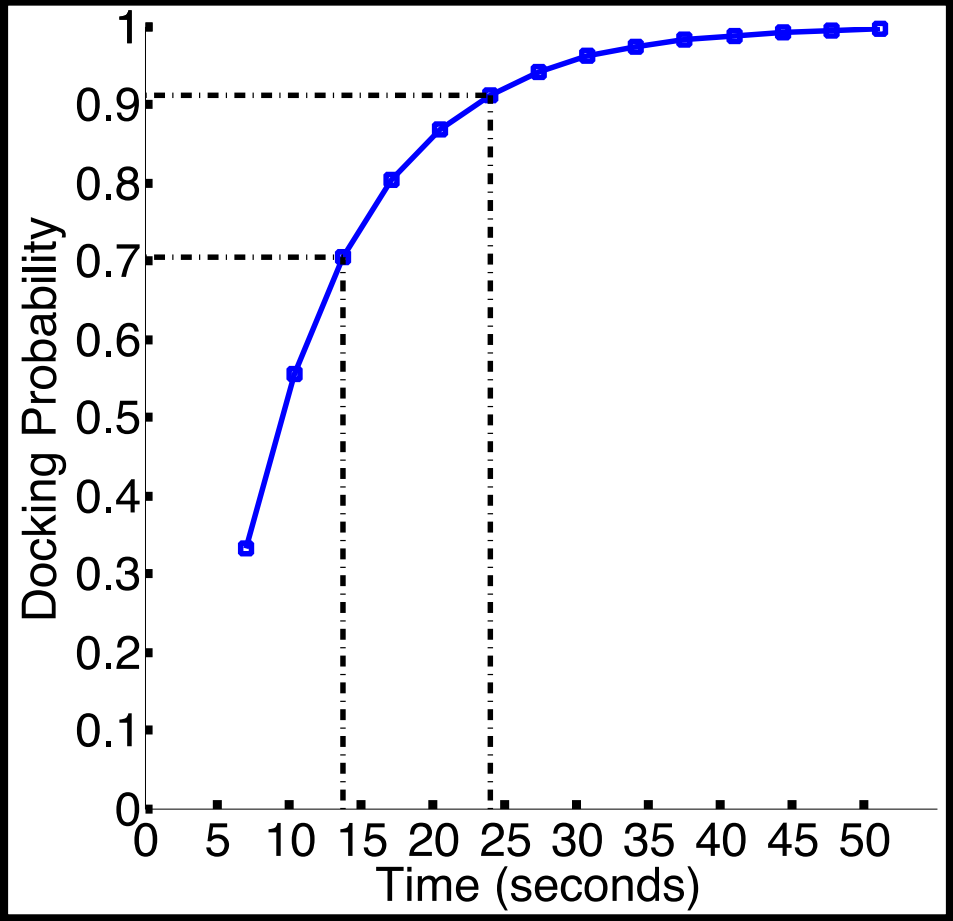
What is Happening Inside the Mechanism



Results

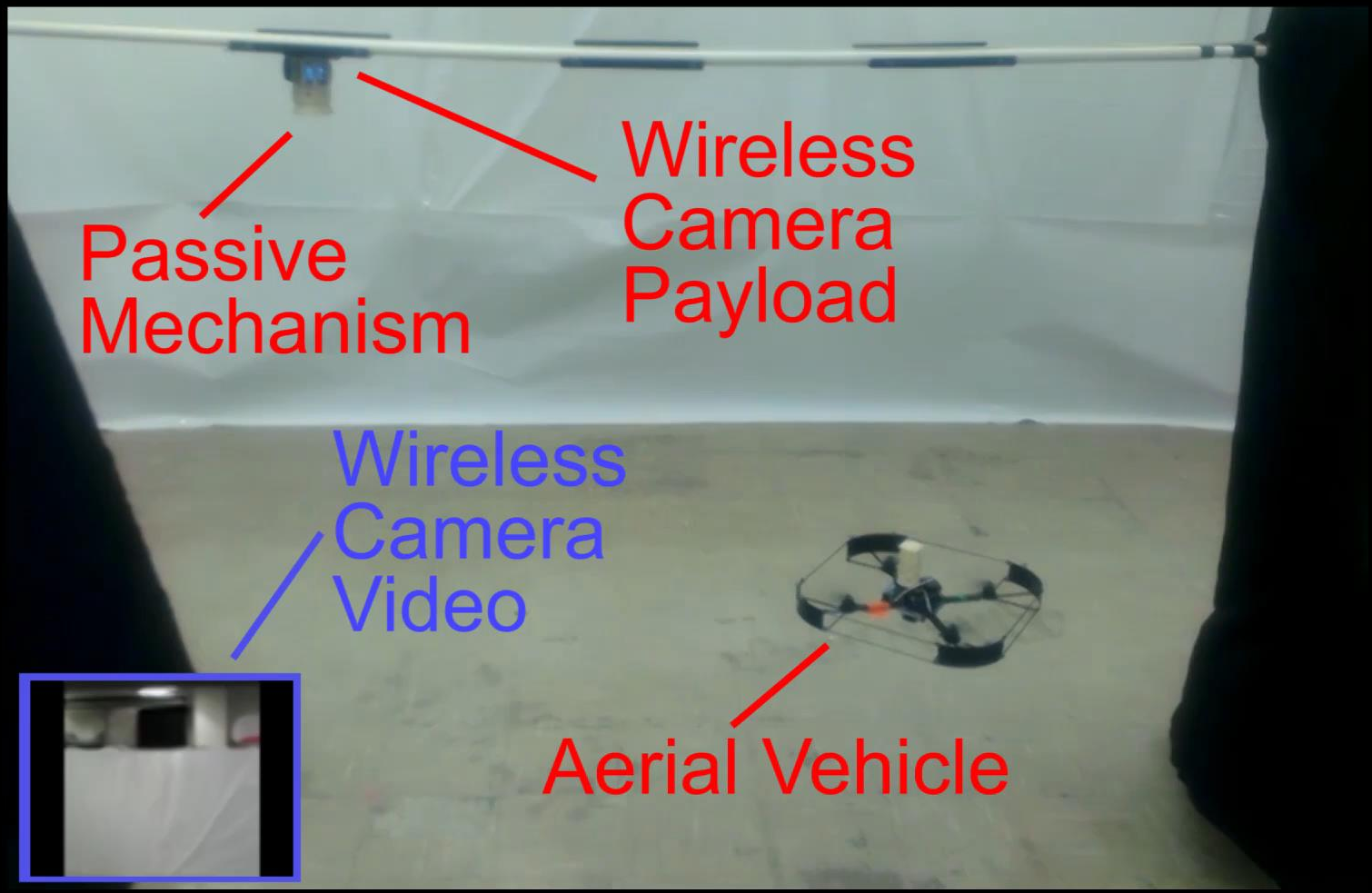
Quantitative Results

We conducted 320 Docking Trials and found that there is more than a 90 % chance of docking after 25 seconds.



Docking Probability vs Time

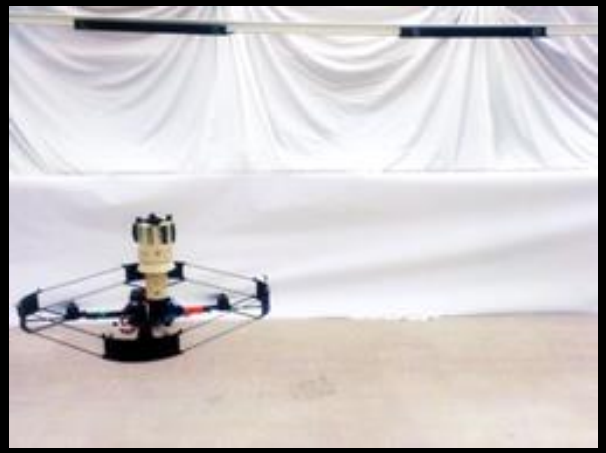
Relocating Cameras on a Construction Site



Conclusion

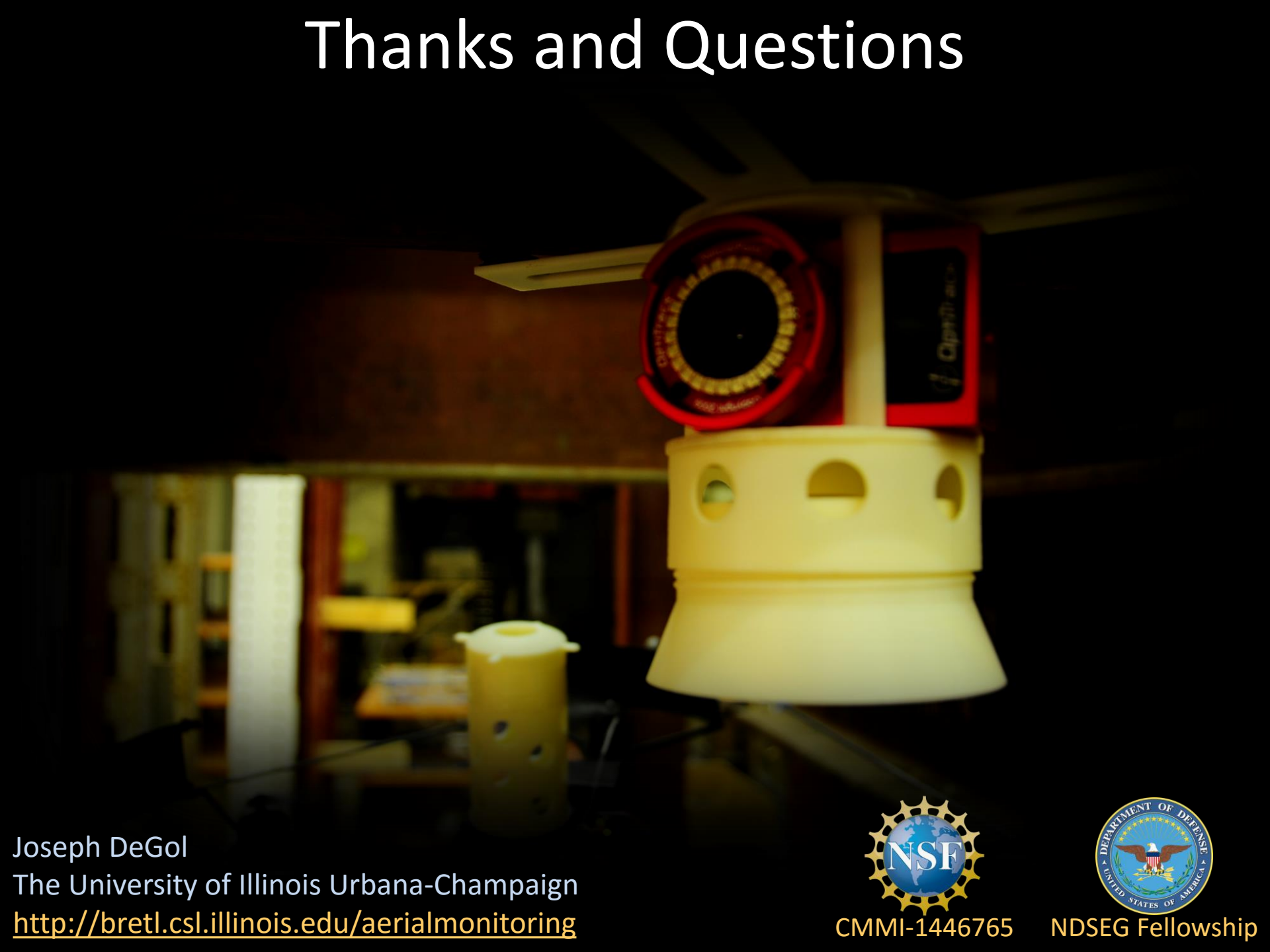
We designed a mechanism for Relocating Payloads with a Quadrotor.

We demonstrate the mechanism being used to relocate cameras.



Open Source: http://bretl.csl.illinois.edu/aerialmonitoring

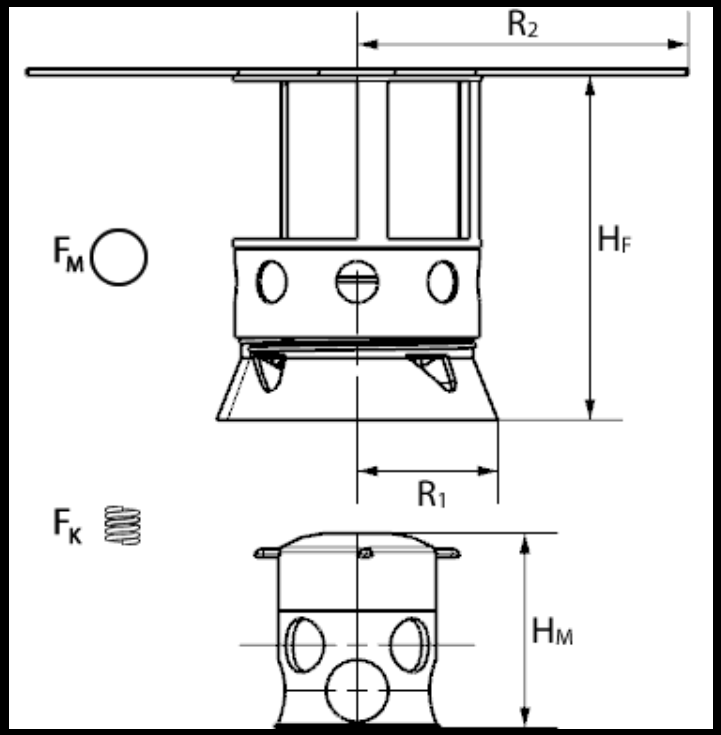
Thanks and Questions



Joseph DeGol
The University of Illinois Urbana-Champaign
http://bretl.csl.illinois.edu/aerialmonitoring

CMMI-1446765 NDSEG Fellowship

Choosing Design Parameters



H_F –

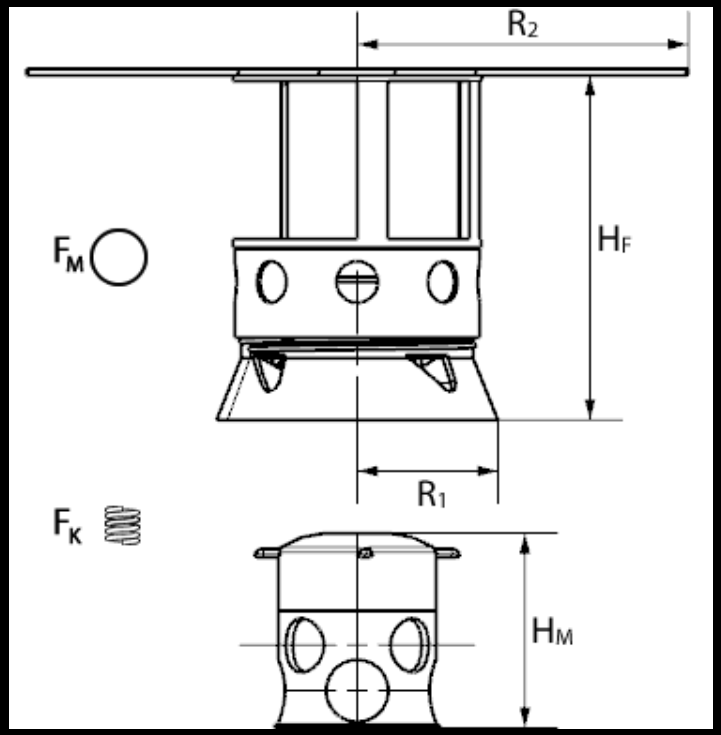
H_M –

R_1 –

F_K –

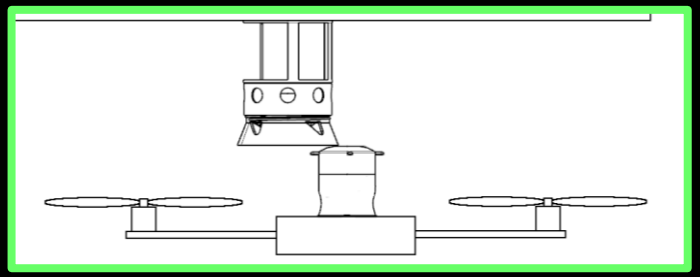
F_M , R_2 –

Choosing Design Parameters



H_F – *Depends on intended payload*

H_M – *Trade-off with Roll/Pitch Error and Slip Recovery*

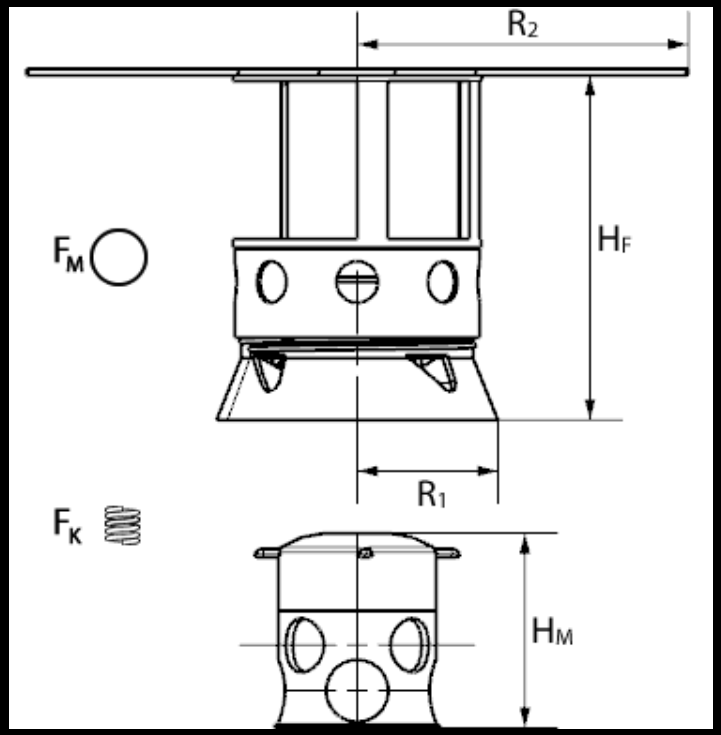


R_1 –

F_K –

F_M , R_2 –

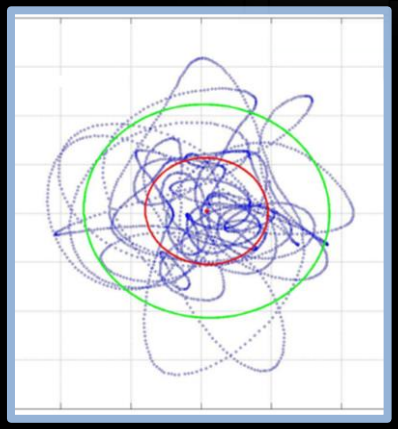
Choosing Design Parameters



H_F – *Depends on intended payload*

H_M – *Trade-off with Roll/Pitch Error and Slip Recovery*

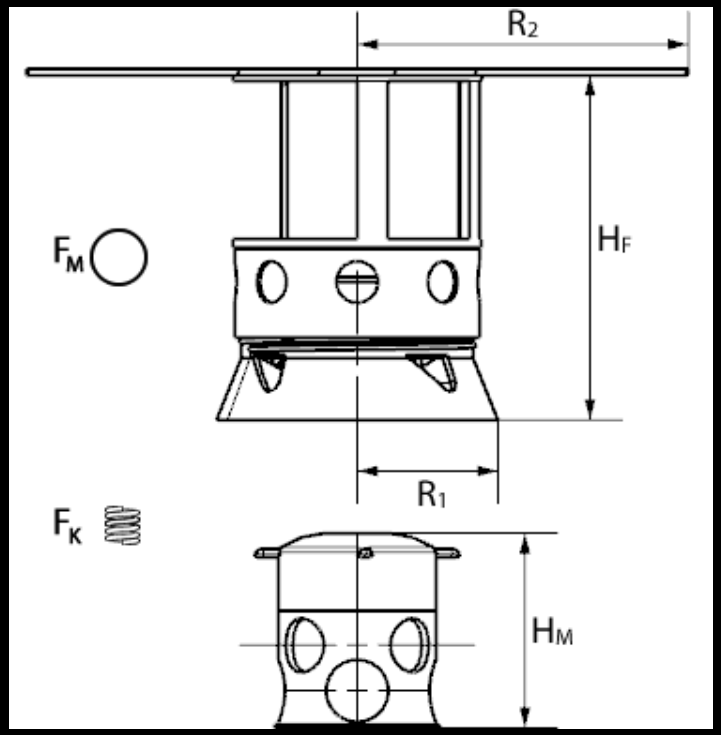
R_1 –



F_K –

F_M , R_2 –

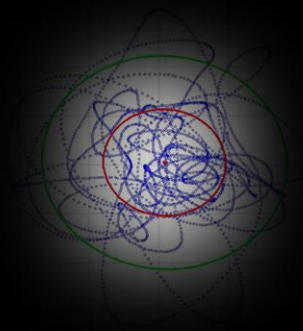
Choosing Design Parameters



H_F – *Depends on intended payload*

H_M – *Trade-off with Roll/Pitch Error and Slip Recovery*

R_1 –

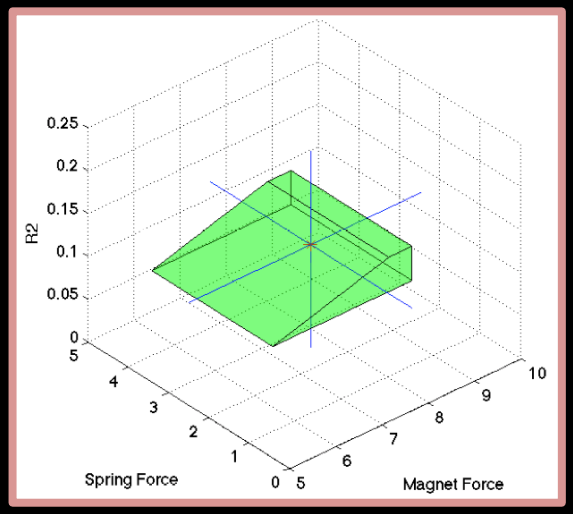


F_K – $Friction < F_K < QuadrotorForce_Z$

F_M , R_2 –

$PayloadWeight < F_M < SystemWeight$

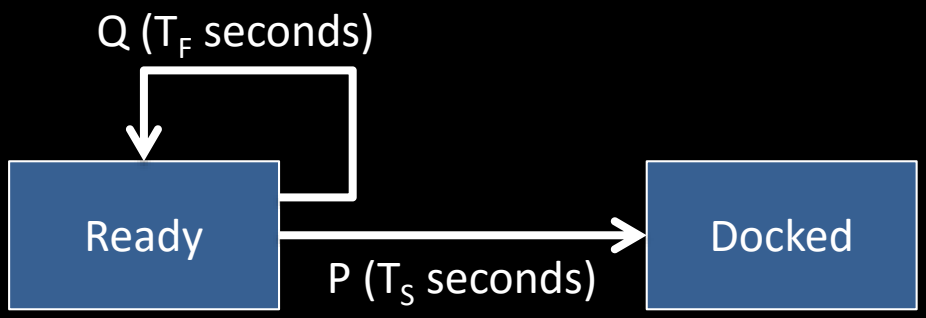
$QuadrotorForce_{\{xy\}} H_F < R_2(F_M + QuadrotorForce_Z)$

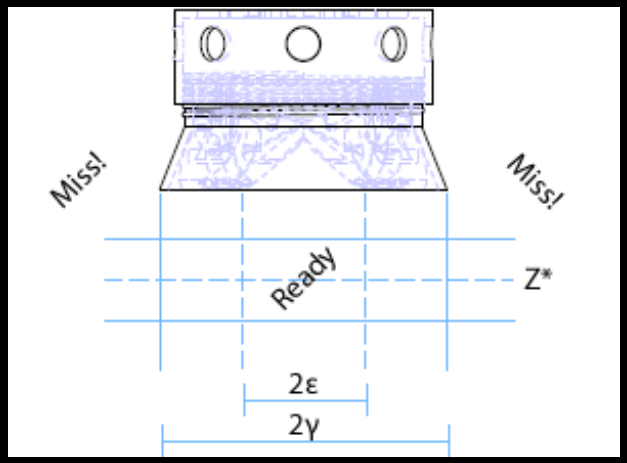


The mechanism weighs less than 100 grams.

Evaluating the Docking Mechanism

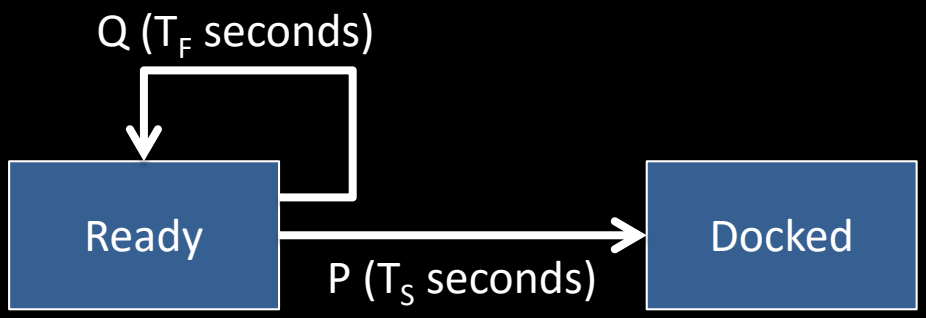
We use standard modeling and trajectory tracking for control.

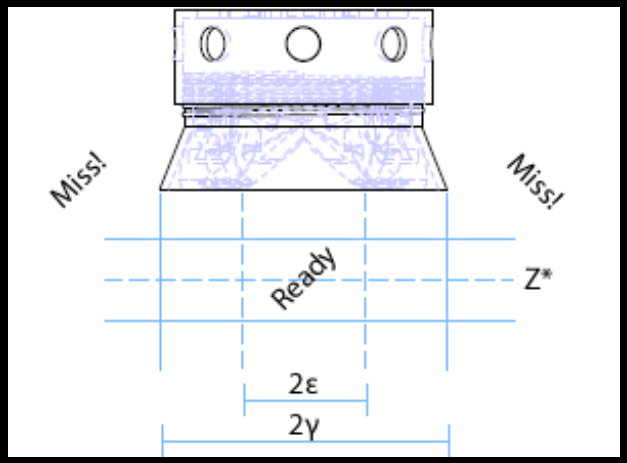




Evaluating the Docking Mechanism

We use standard modeling and trajectory tracking for control.





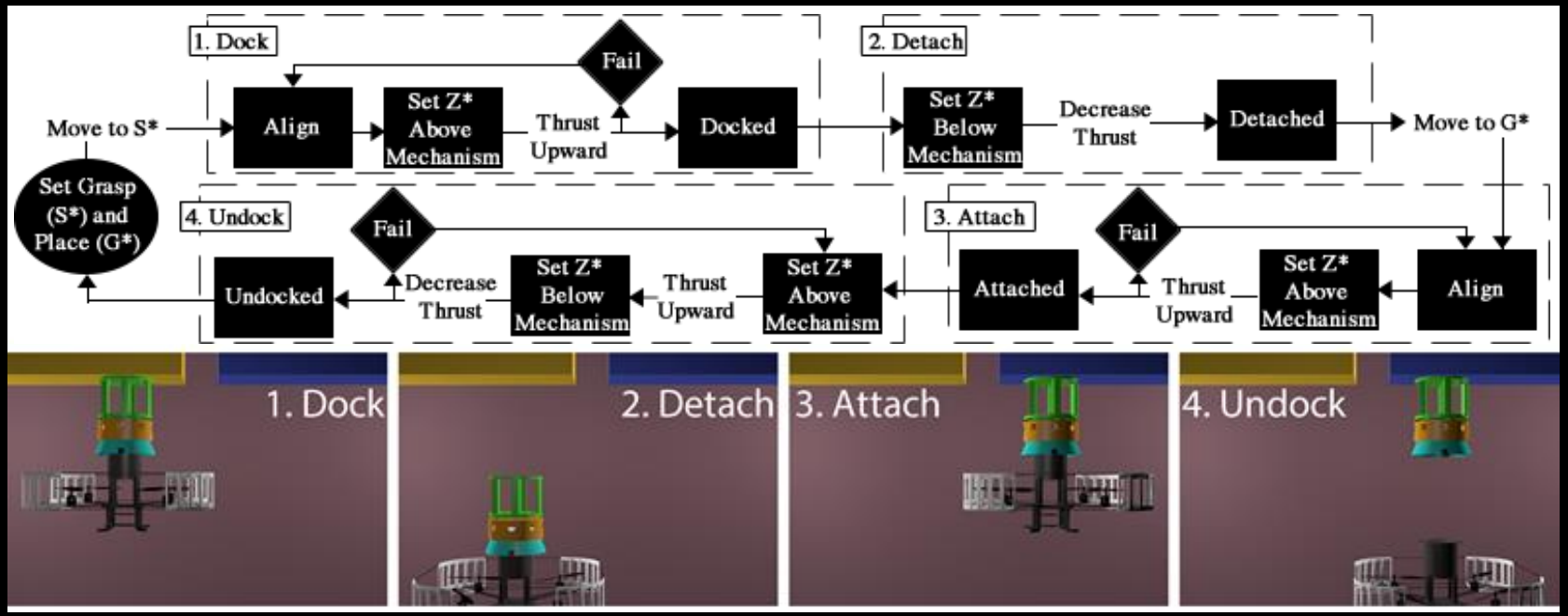
We ran 320 docking trials; 20 per parameter permutation for
κ: (-0.50, -0.33, -0.25, -0.20 m/s)
ε: (γ = 0.0425 m, γ/2, γ/4, γ/8)

κ (m/s)	ε	P	T_S (s)	T_F (s)	E[T_D] (s)
-0.50	γ	0.33	7.02	3.39	13.80
-0.50	γ/8	0.35	7.01	6.69	19.27
-0.33	γ/4	0.36	9.52	3.17	15.23
-0.33	γ/8	0.37	9.52	6.95	21.32
-0.25	γ/4	0.36	12.01	2.88	17.05
-0.20	γ	0.28	14.51	3.39	23.33
-0.20	γ/4	0.29	14.52	5.27	27.16

Docking Success

We use standard modeling and control to run 320 docking trials; 20 per parameter permutation for κ (-0.50, -0.33, -0.25, -0.20) and ε (γ = 0.0425m, γ/2, γ/4, γ/8).

We ran 320 Docking Trials, 20 per parameter permutation



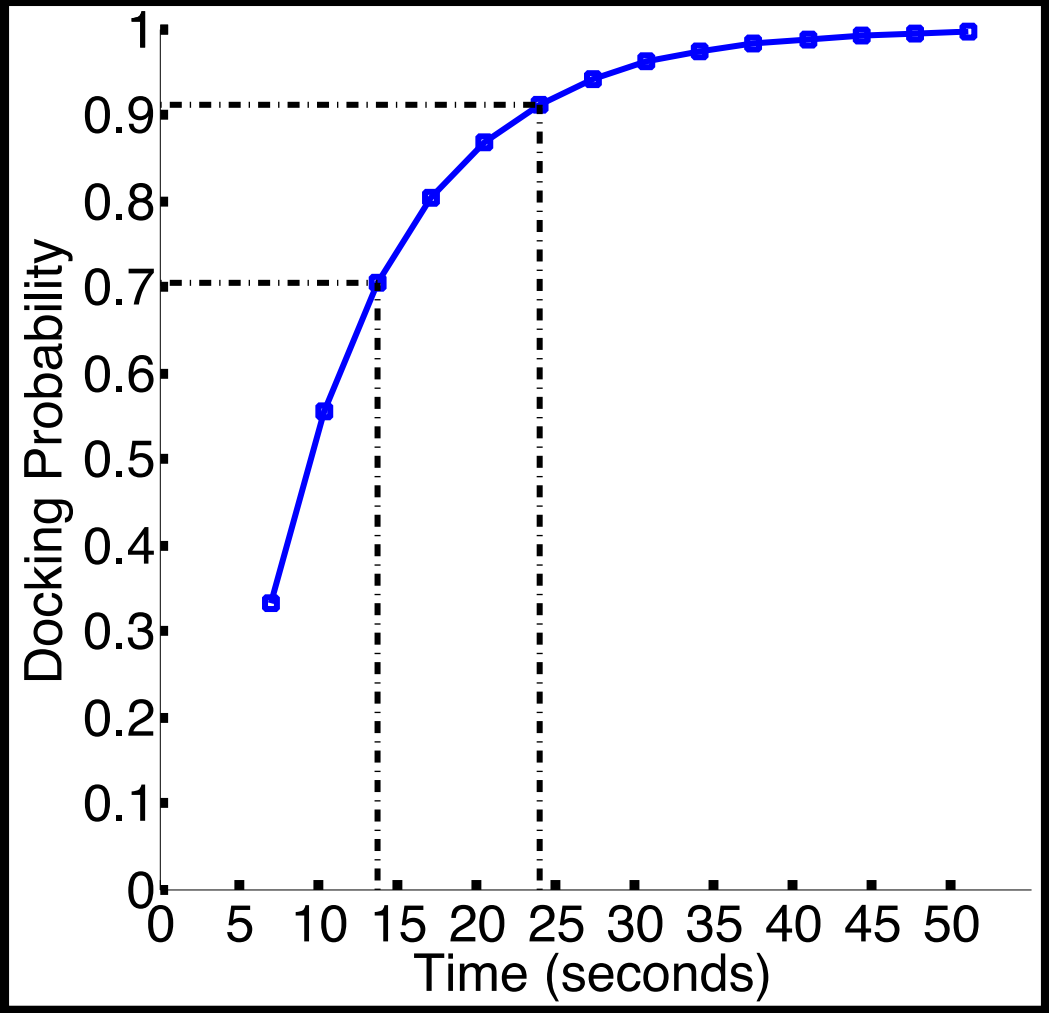
Evaluating the Docking Mechanism

We ran 320 docking trials; 20 per parameter permutation for
κ: (-0.50, -0.33, -0.25, -0.20 m/s)
ε: (γ = 0.0425 m, γ/2, γ/4, γ/8)

κ (m/s)	ε	P	T_S (s)	T_F (s)	$E[T_D]$ (s)
-0.50	γ	0.33	7.02	3.39	13.80
-0.50	γ/8	0.35	7.01	6.69	19.27
-0.33	γ/4	0.36	9.52	3.17	15.23
-0.33	γ/8	0.37	9.52	6.95	21.32
-0.25	γ/4	0.36	12.01	2.88	17.05
-0.20	γ	0.28	14.51	3.39	23.33
-0.20	γ/4	0.29	14.52	5.27	27.16

Evaluating the Docking Mechanism

Docking probability versus time for the smallest $E[T_D]$



κ: -0.50 m/s

ε: γ = 0.0425 m

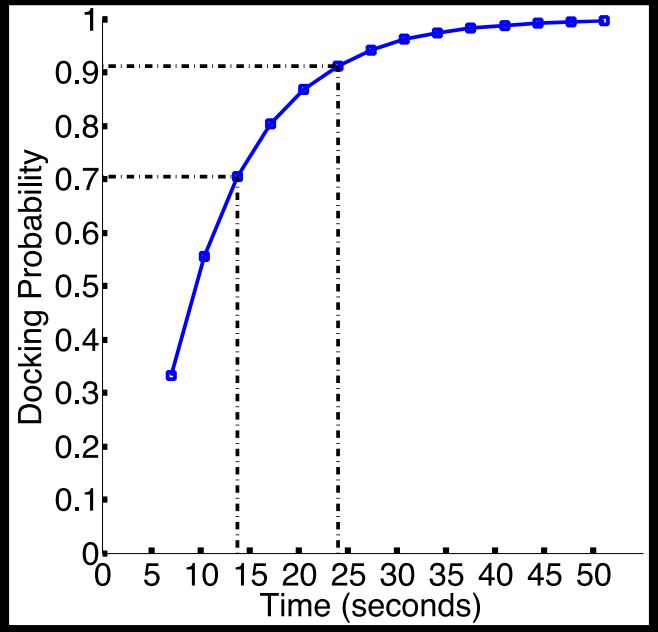
There is more than a 90 % chance of docking within 25 seconds.

Evaluating the Docking Mechanism

We ran 320 docking trials; 20 per parameter permutation for
κ: (-0.50, -0.33, -0.25, -0.20 m/s)
ε: (γ = 0.0425 m, γ/2, γ/4, γ/8)

κ (m/s)	ε	P	T_S (s)	T_F (s)	$E[T_D]$ (s)
-0.50	γ	0.33	7.02	3.39	13.80

Docking probability versus time for the smallest $E[T_D]$



There is more than a 90 % chance of docking within 25 seconds.