Integrity ★ Service ★ Excellence

Investigation of a simple visual system for flight control.

July 2011

Jennifer Talley, Ph.D.
Research Biological Scientist
RWGII
Air Force Research Lab

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
JUL 2011	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Investigation of a simple visual system for flight control	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Air Force Research Lab**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM202973. BioMav SOAR 2. Held at Chilworth Manor, United Kingdom on July 12-15, 2011, The original document contains color images.

14. ABSTRACT

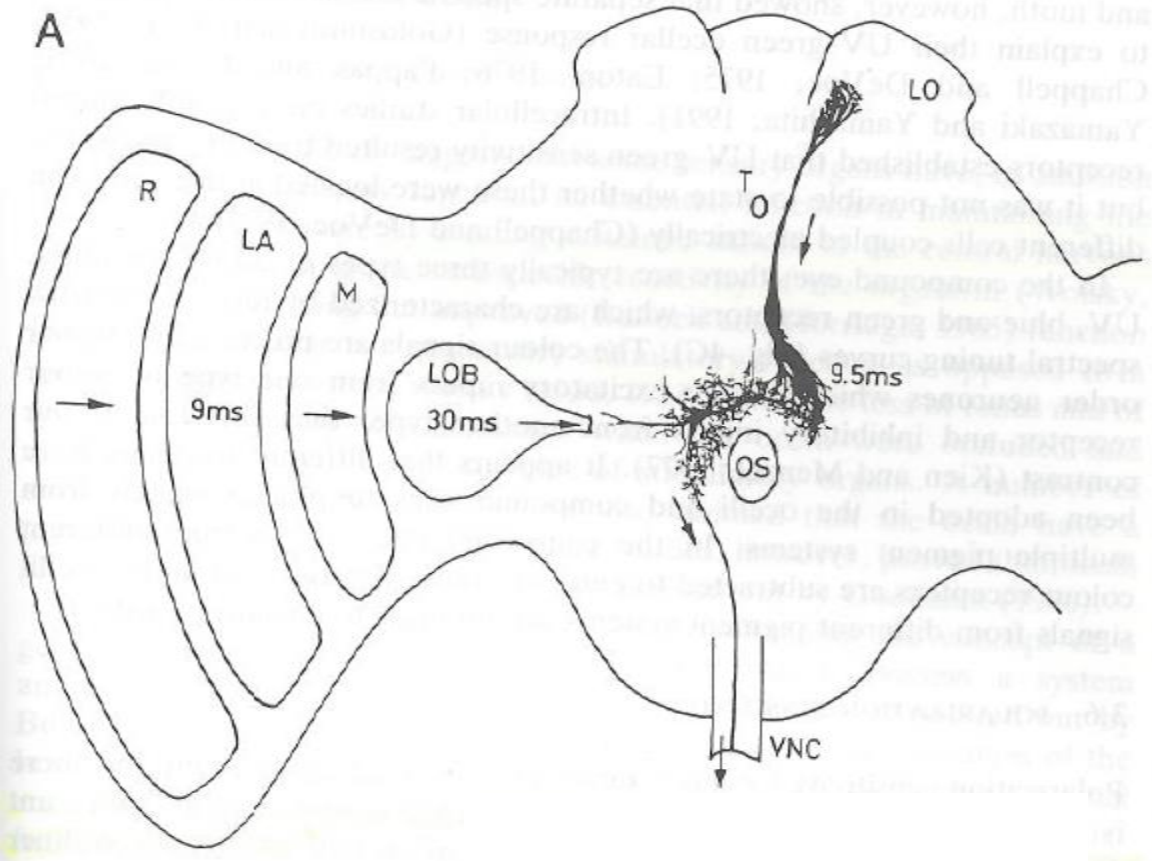
15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**25**	

Hypothesis

Characterizing the physiology of ocellar systems and associated behaviors from a wide diversity of insects could ultimately lead to a more complete understanding of insect flight control.

Ocelli are faster than the compound eyes.



Visual system	Latency of pathway	Minimum connections
Compound eyes	25-35 ms	4 interneruons
Ocelli	9ms	1 interneuron

Bug Faces: Ocelli are anatomically diverse.

Mizunami, The diversity of insect ocellar systems, 1994

Identifying good candidates for study.

- Different sensor suites different behaviors
- Same sensor suites similar behaviors
- Different sensor suites similar behaviors
  - Different sensors measure/use same information? Therefore behavior requires that piece of information.
  - Using different information but getting same outcome? Behavior can be produced using different pieces of information.
- Same sensor suites different behaviors
  - Different ecological/environmental demands? Possible to produce the behavior under the right conditions.
  - Using same information differently? Sensors have been co-opted for different purpose.

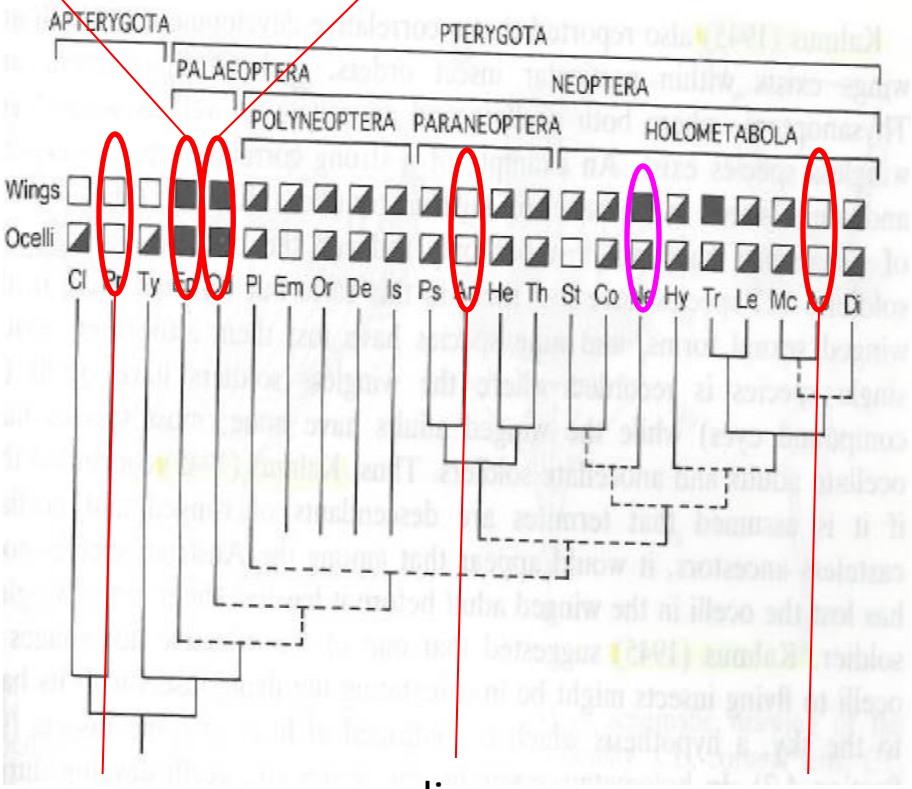
*Statements assume that "same sensor" means measuring the same information.

Correlative development of wings and ocelli.

Dragonflies and damselflies

mayflies

Insect orders



proturans

lice

Fleas

All have wings or ocelli

None have wings or ocelli

Some have wings or ocelli

Mizunami, The diversity of insect ocellar systems, 1994

Identifying good candidates for study.

- Different sensor suites similar behaviors
  - Similar flight behavior in insects with different sensors (some have ocelli and some do not).
  - Dragonflies vs. nearctic owlflies
- Same sensor suites different behaviors
  - Very different flight, but all have the same sensor (all have ocelli).
  - Crane flies vs. robberflies vs. hoverflies

Properties of ocelli have not been widely investigated.

Table 5. Spectral sensitivity of ocellar and compound eye receptor cells [a]

Wavelength (nm)		300 350 400 450 500 550
Fly (*Calliphora*)	sc	
	sc	
Hardie (1979)	sc	
	sc	
Kirschfeld and Lutz (1977)	erg	
Fly (*Drosophila*)	erg	
Harris et al. (1976)	erg	
Stark et al. (1977)	erg	
Hu et al. (1978)	erg	
Milkweed bug (*Oncopeltus fasciatus*)	erg	
Stusek and Gogala (1971)	erg	
Praying mantis (*Tenodera sinensis*)	erg	
	erg	
Sontag (1971)	erg	
Worker honeybee (*Apis mellifera*)	sc	
	sc	
Menzel and Blakers (1976)	sc	
	sc	
Goldsmith and Ruck (1958)	erg	
Dragonfly	sc	
Laughlin (1976) *Hemicordulia tau*	sc	
	sc	
	sc [b]	
Chappell and DeVoe (1975)[c]	sc	
	sc	
Cockroach (*Periplaneta americana*)	sc	
Mote and Goldsmith (1970)	sc	
Goldsmith and Ruck (1958)	erg	
Moth	erg [d]	
Pappas and Eaton (1977) *Manduca sexta*		
Eaton (1976) *Trichoplusia ni*	erg	

[a] Points along any single horizontal line represent spectral sensitivity maxima determined by either single cell intracellular recording (sc) or the electroretinogram (erg). ●, spectral sensitivity maxima for compound eye receptor cells; ○, spectral sensitivity maxima for ocellar receptor cells; ←, peak UV sensitivity possibly at shorter wavelength

[b] Range of peak sensitivity for linked pigment cells

[c] UV-Green in *Anax junius*, *Libellula pulchella* and *Aeschna tuberculifera*. UV-Blue-Green only in *A. junius*

[d] Internal ocellus

Goodman, Organization and physiology of the insect dorsal ocellar system, 1981

Proposed experiments will characterize ocellar properties.

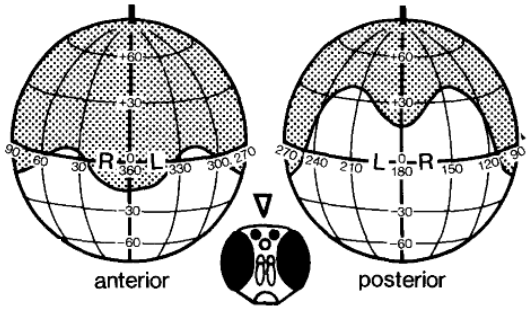
Measured properties:

- **Spectral Sensitivity**

- **Flicker Fusion Frequency**
- **Field of View & directional sensitivity**
- **Focal Length and spatial resolution**

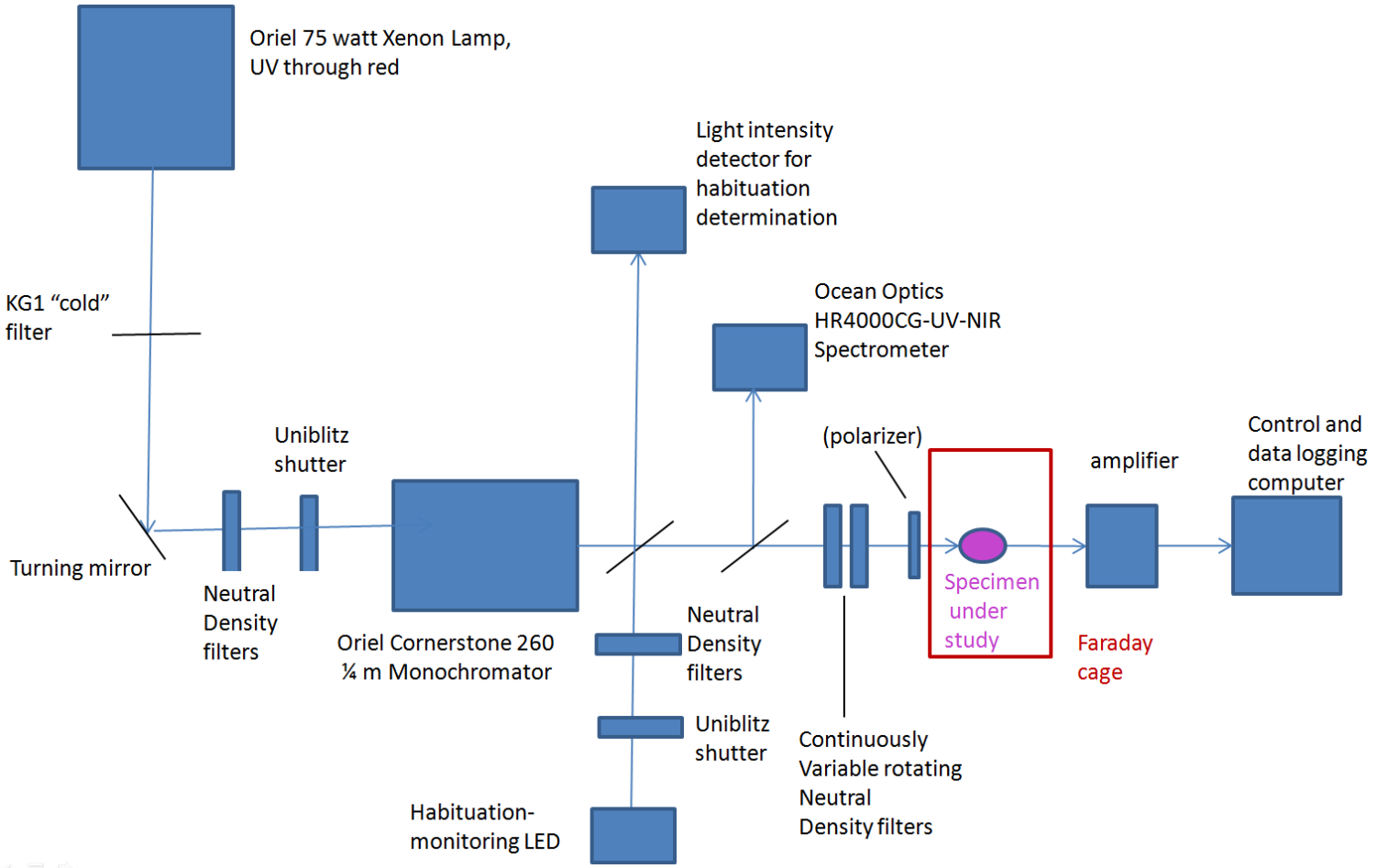
Techniques:

- **Electroretinogram**
- **Extracellular from ocellar nerve**
- **Intracellular from L neurons**

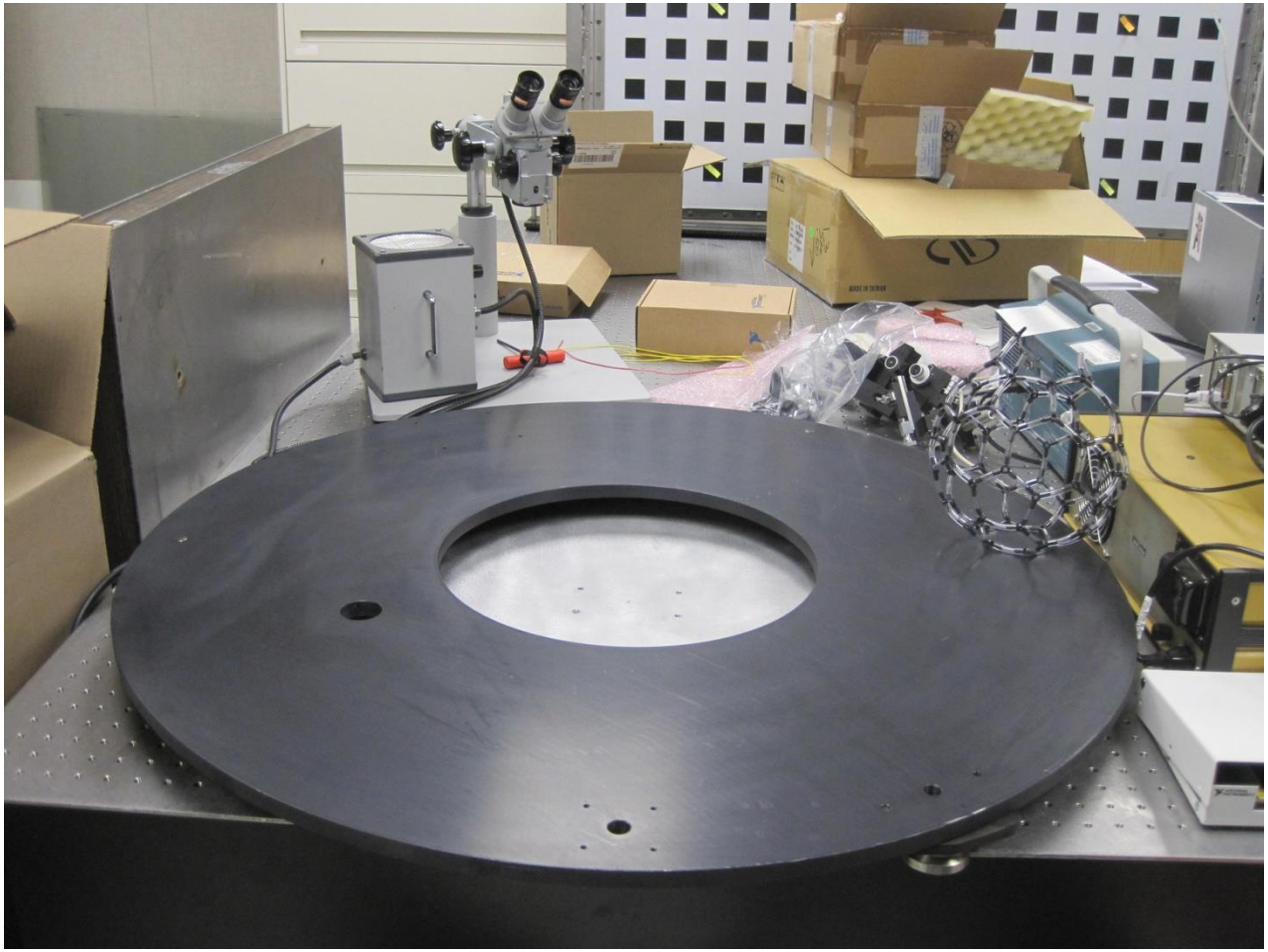


Schuppe and Hengstenber, Optical properties and functional role of the dorsal ocelli1993

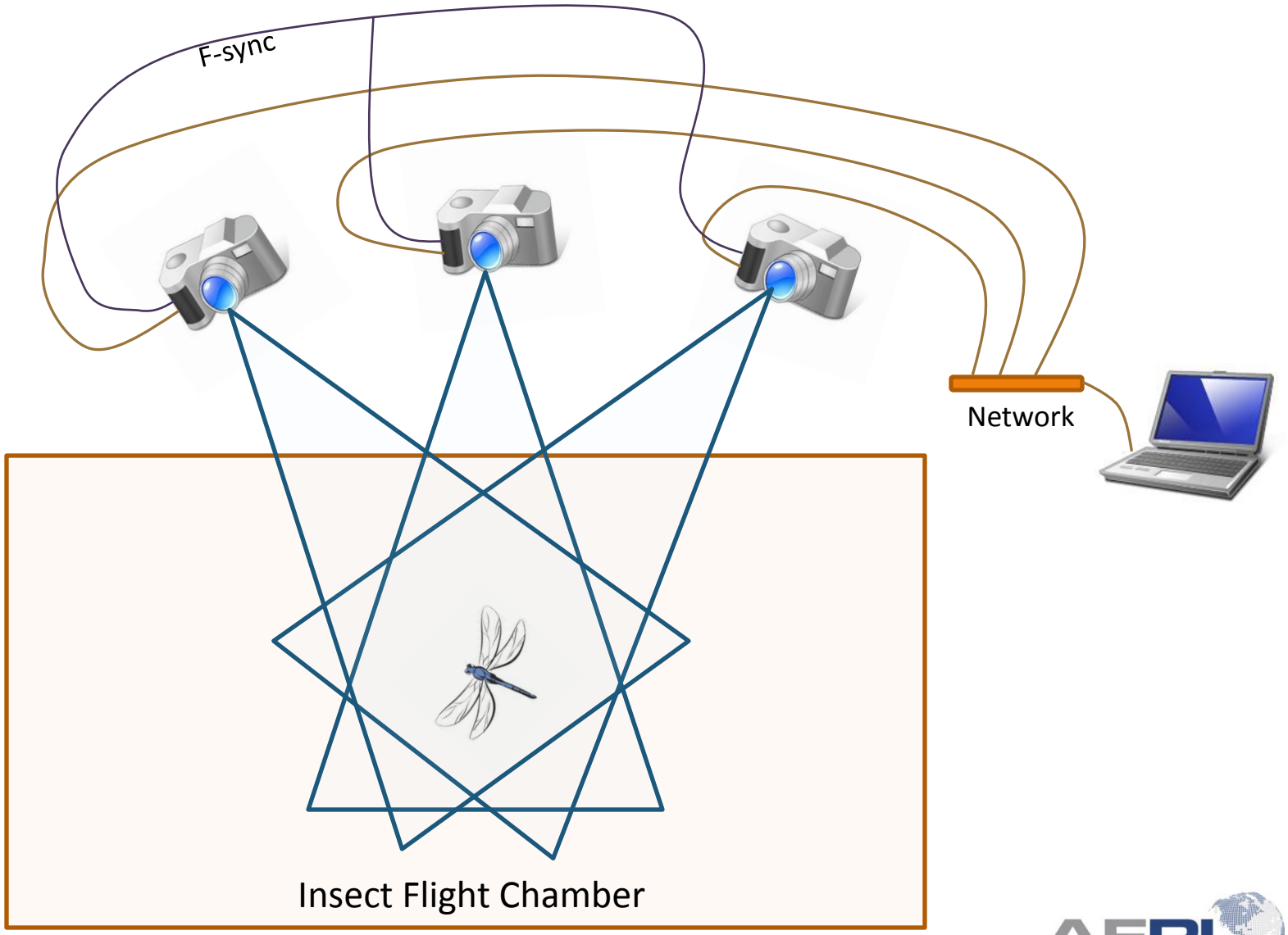
Test spectral responsivity, FFF



Field of view, directional sensitivity, spatial resolution.

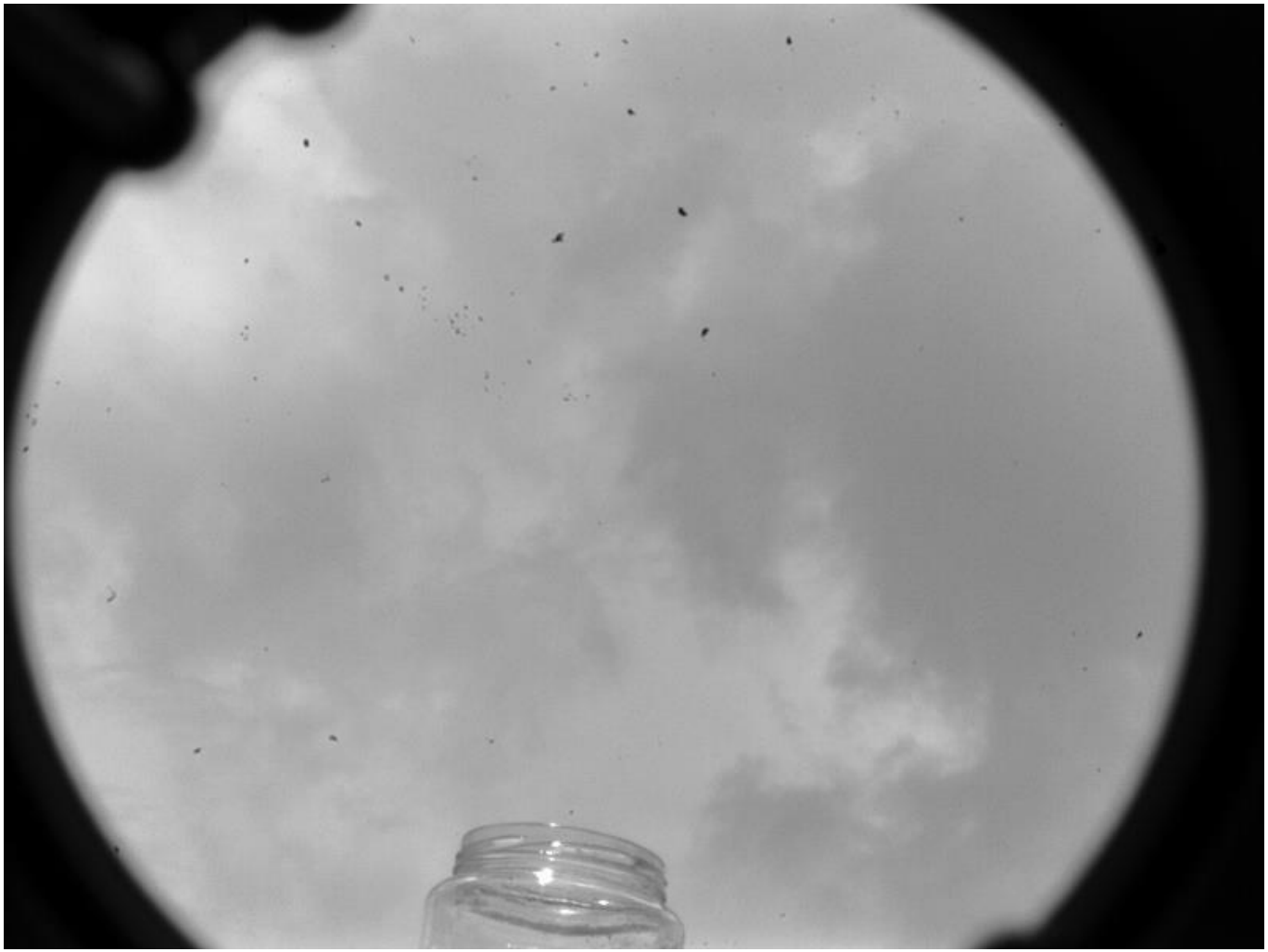


Insect Flight setup, by David Forester.

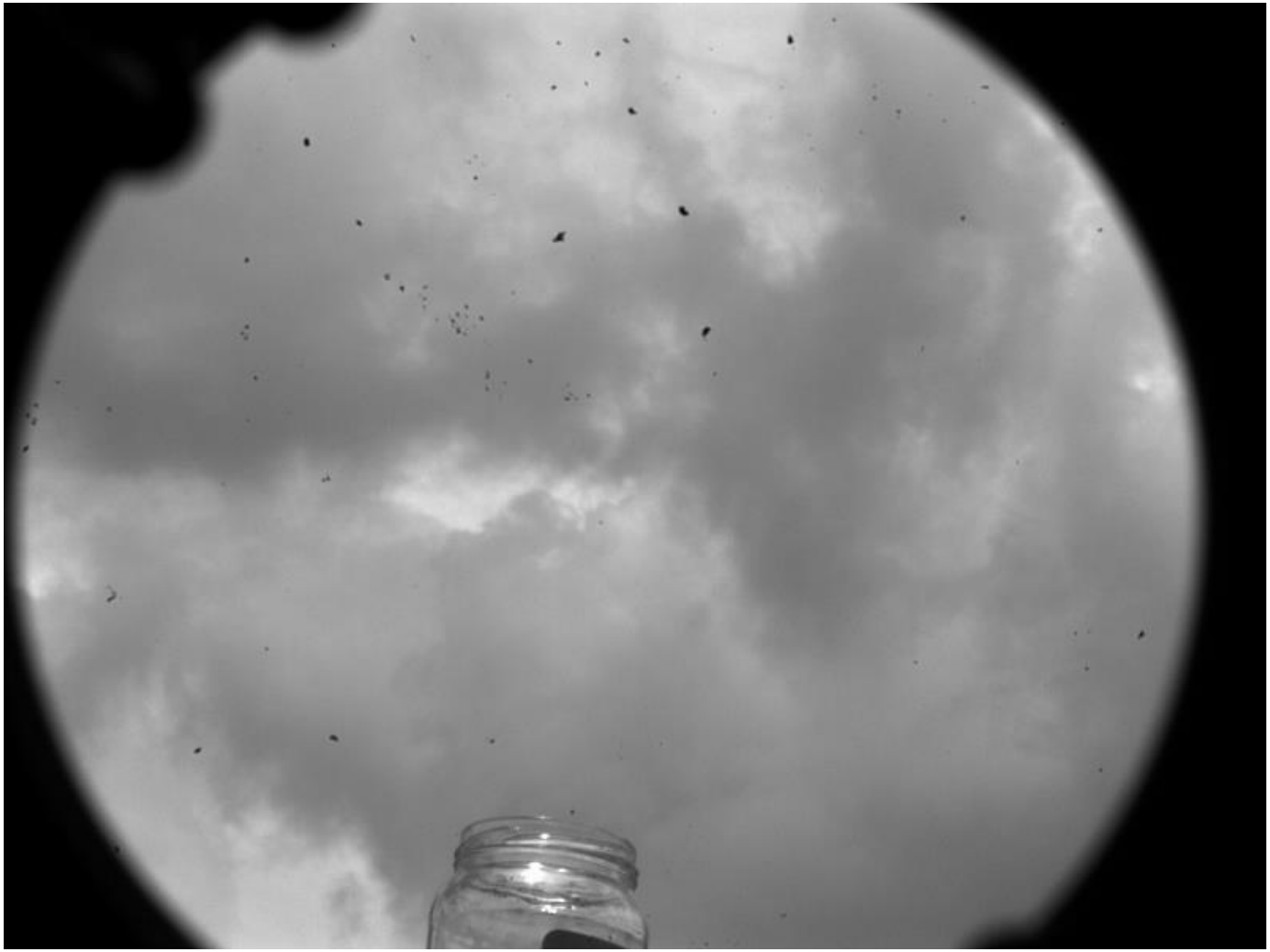


Similar behaving insects, different sensors.

Dragonfly in field

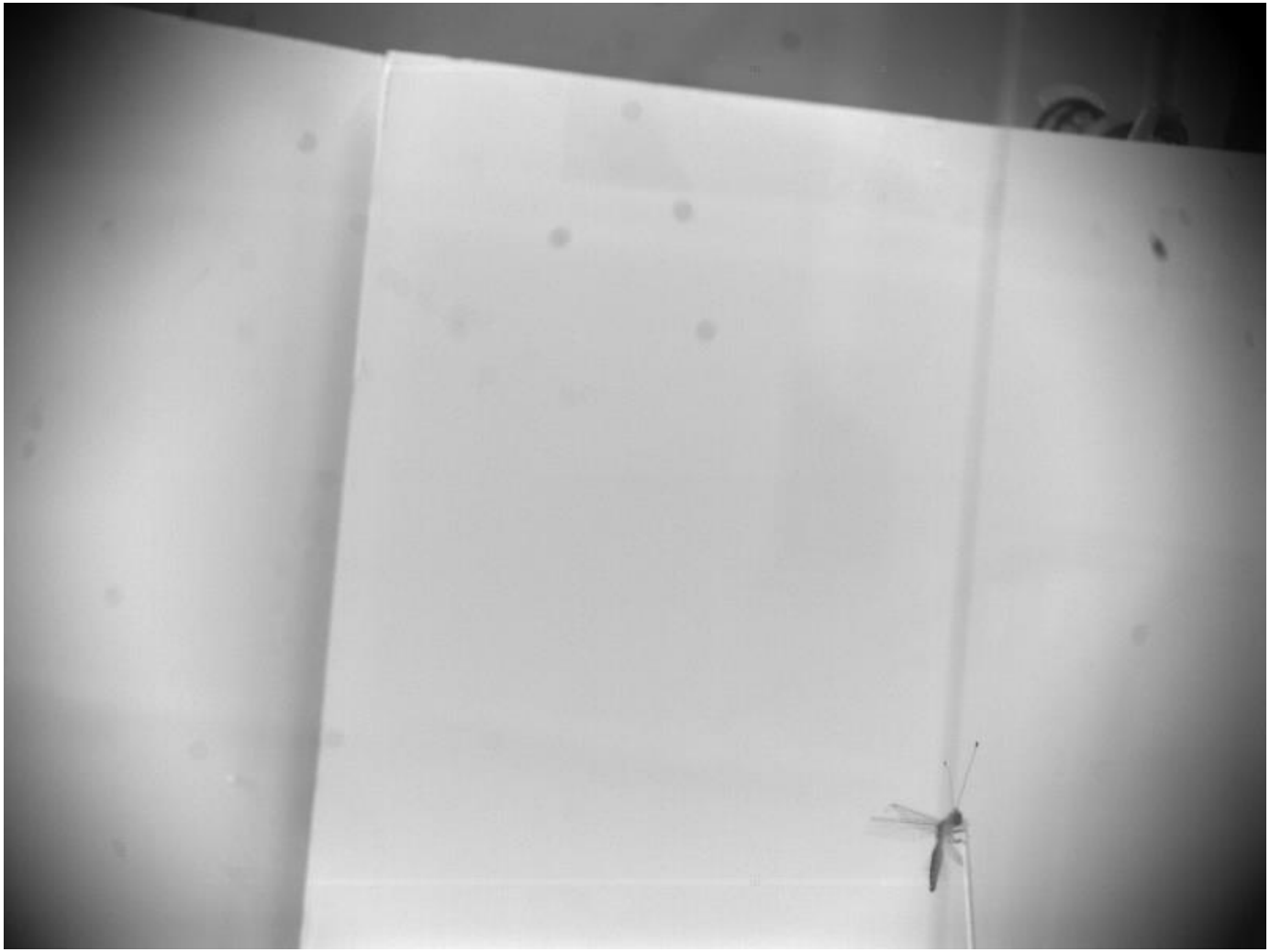


Dragonfly in field, recovers from perturbation.



Owlfly horizontal dorsal flight.

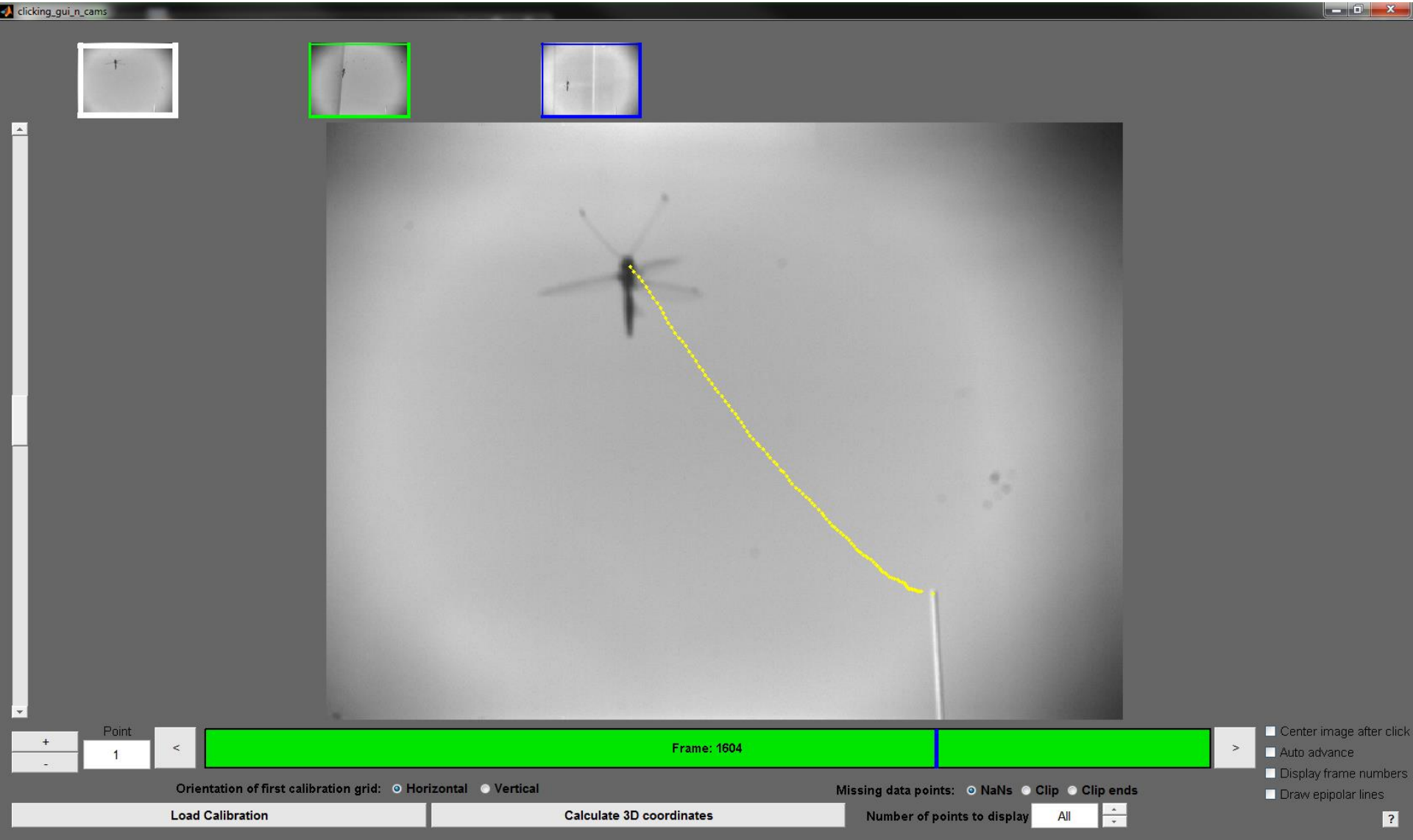
Owlfly vertical flight.



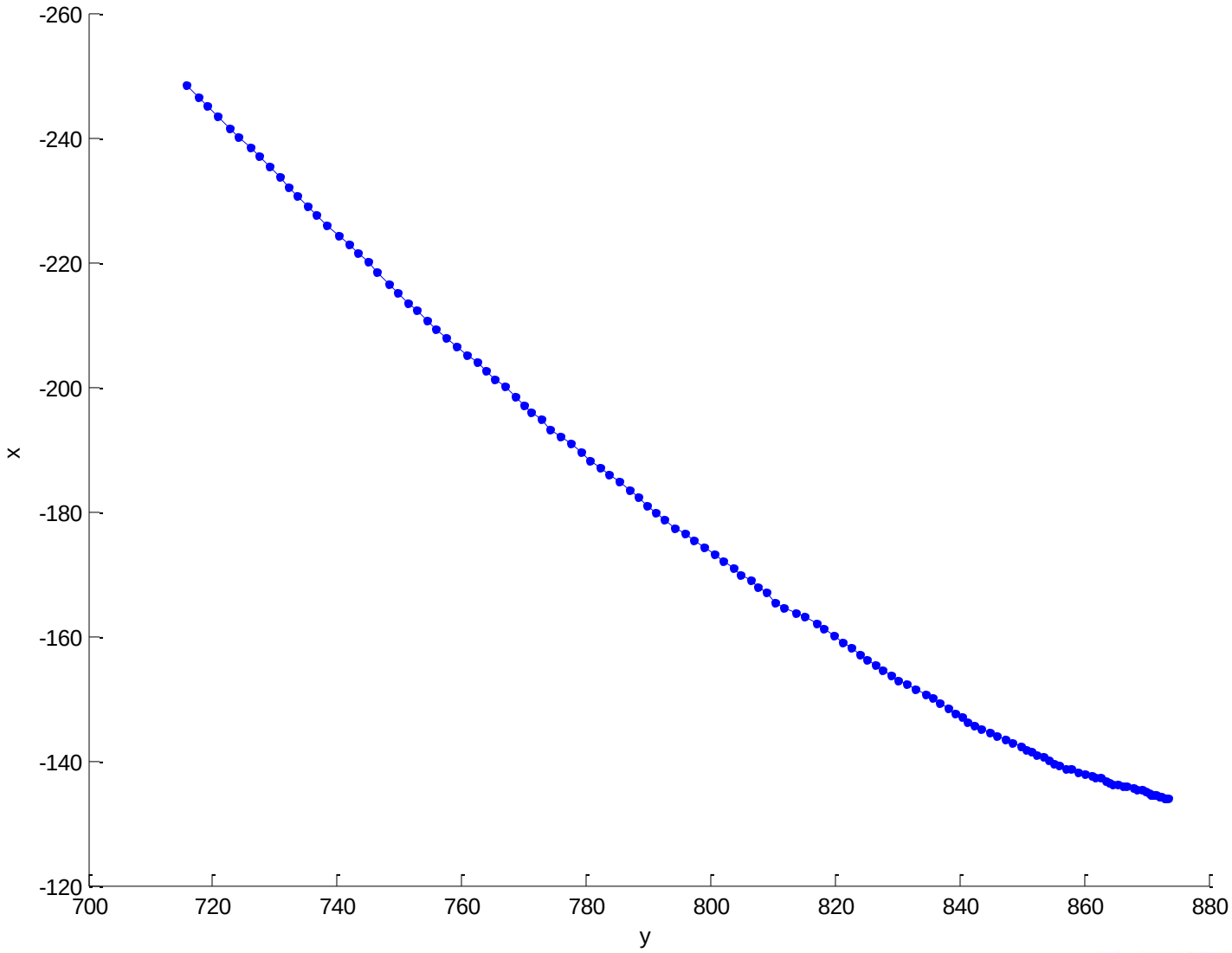
Owlfly vertical backward flight.

Owlfly upside down flight.

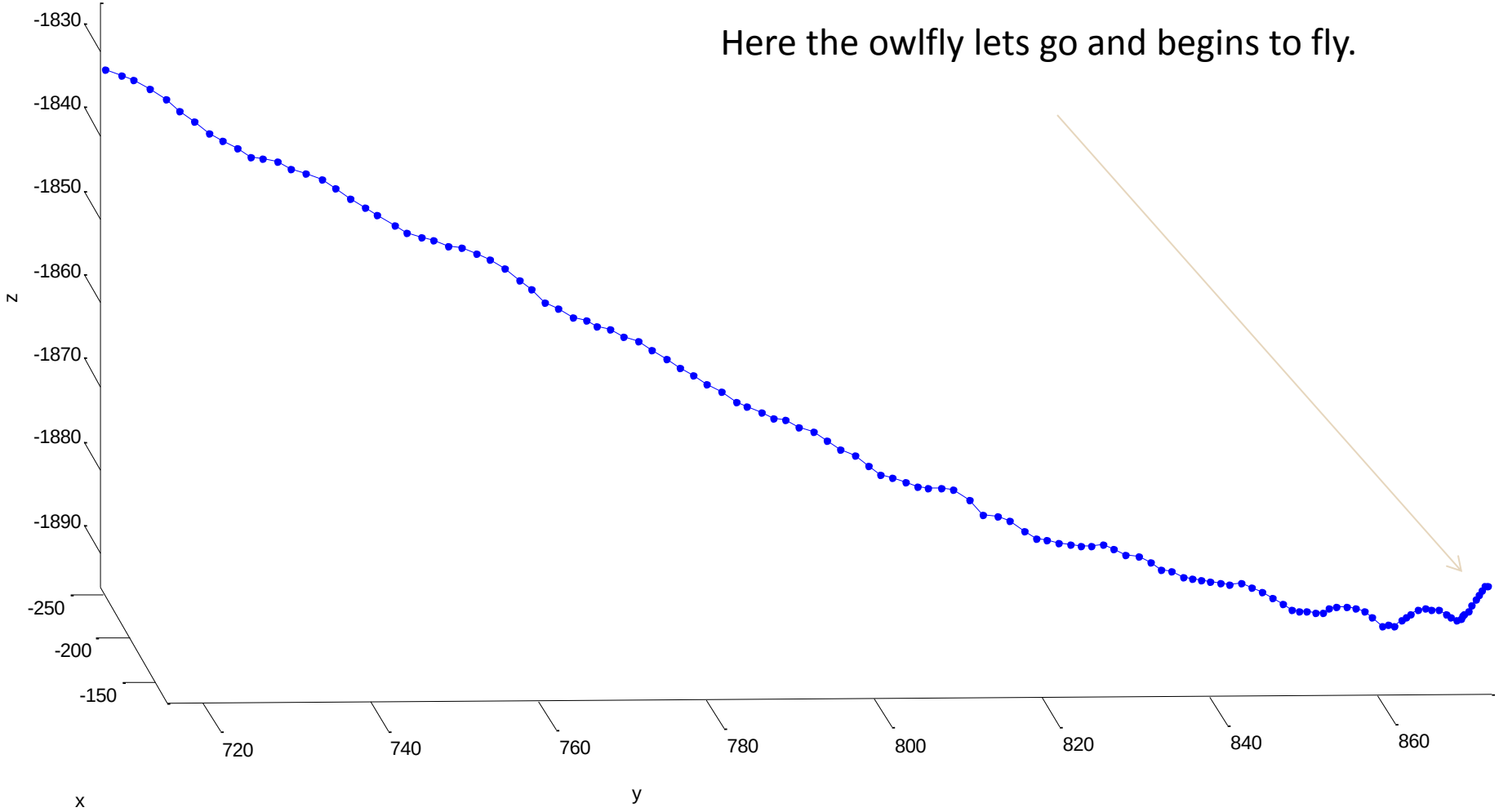
screenshot from the tracking software.

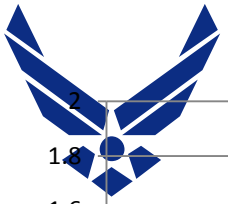


Tracking point on the head – this 2D view is similar to the tracked points shown on the previous slide.



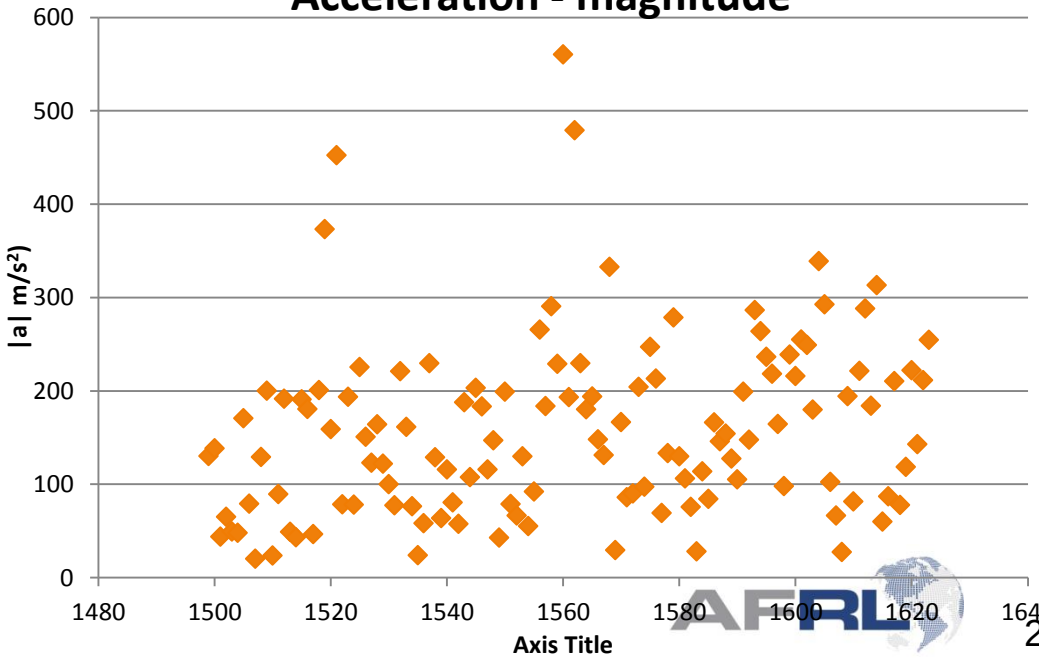
Tracking point on the head – 3D view, like previous plot, but slightly rotated. Showing some interesting features when the owlfly releases and begins to fly.





Velocity - magnitude

Acceleration - magnitude



Way forward.

- Wing beat frequency
- Recovery after perturbation.
  - Normalize to body size?
- Auto tracking vs. manual tracking.
- Manipulate sensors.
- Connect to physiology measured from sensors.


AIR FORCE RESEARCH LABORATORY