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14. ABSTRACT Clinical exposure to high power radiofrequency (RF) energy has been studied for its ability to both warm and destroy tissue through heat deposition.					
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Probability of Injury from RF Exposure (PIRE)

28 June 2018

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Integrity ★ Service ★ Excellence

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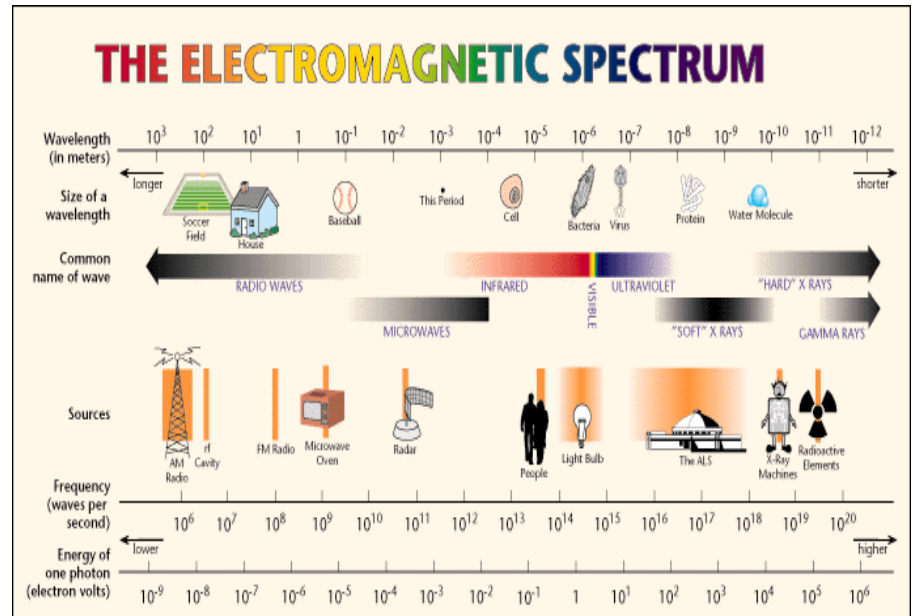




Outline



- Radio Frequency Bioeffects Branch Introduction
- Radio Frequency Context
- PIRE Introduction
- Bioeffects Modeling
- Coupon Study
- Panniculus Study
- Conclusion





Radio Frequency Bioeffects Branch



Located in San Antonio,
TX -- Roots back to
1950's

Full bio-analysis from
behavior to atomic level

Exploring low to high
power exposures

Computational analysis
& simulation

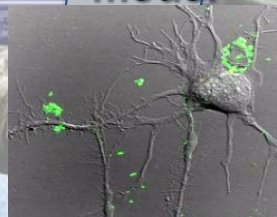
RF sources (AF, Navy, &
Army)

12 Chambers/labs

GOALS

RF Bioeffects Models
RF Protection

Develop *in vitro*
model



Expand to
in vivo



Algorithms

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

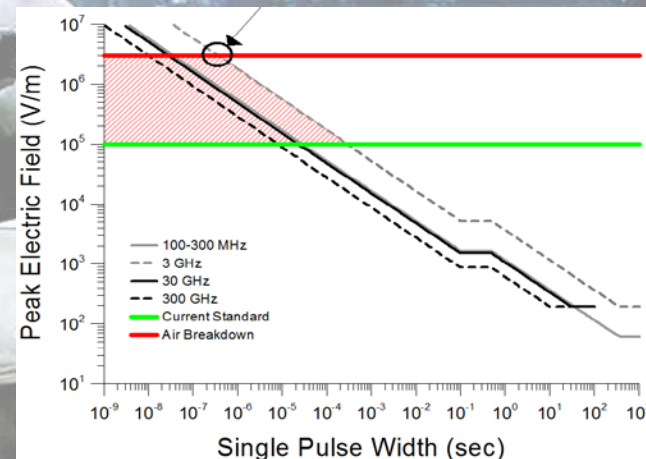
$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

Whole
Body
Models



Application

Computation

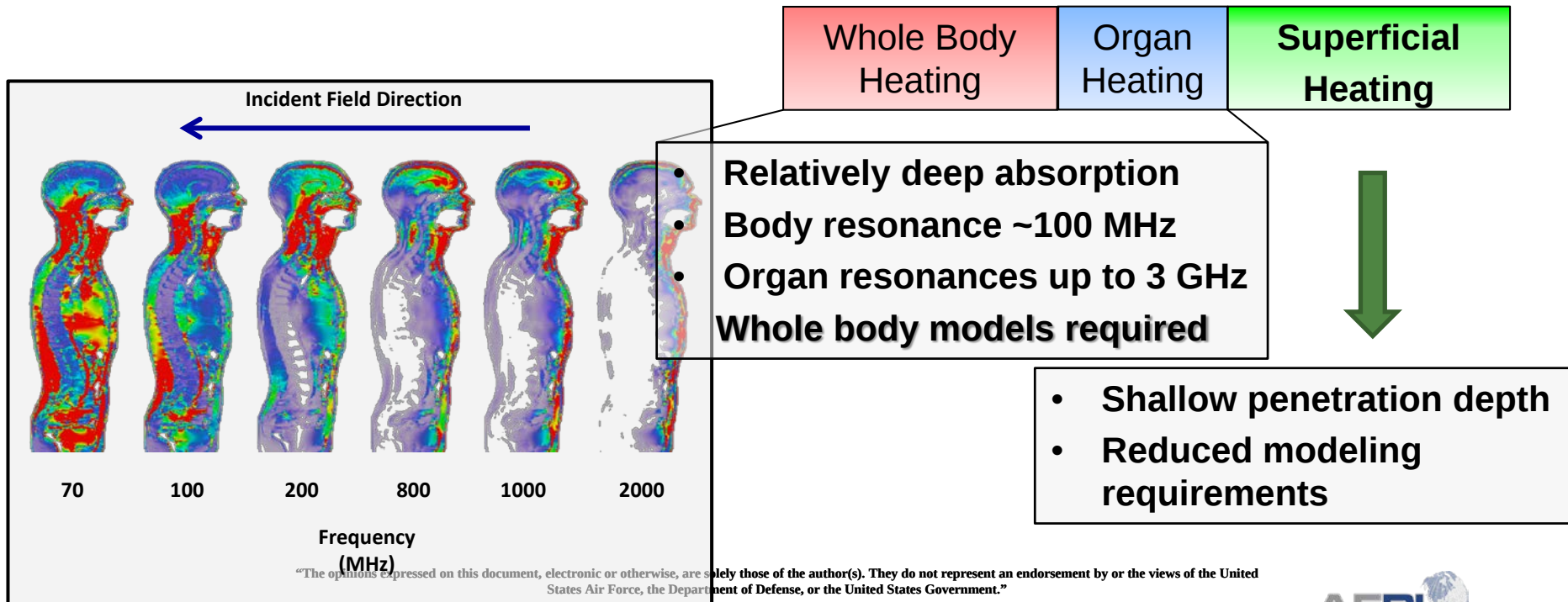
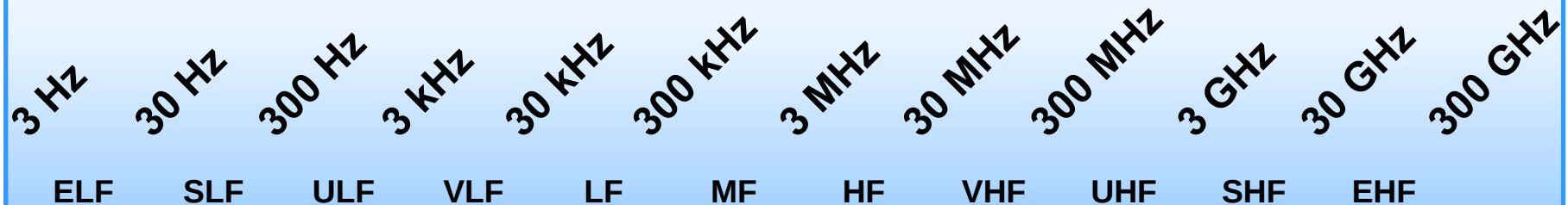




RF Spectrum & Absorption Depth



Radio Waves



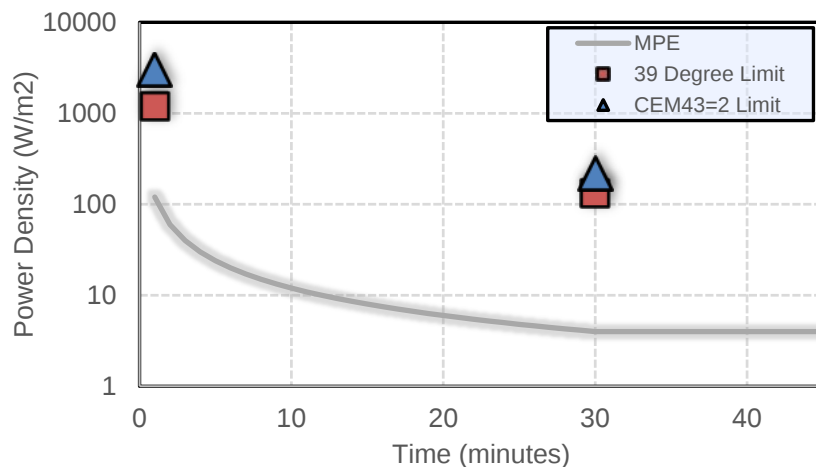
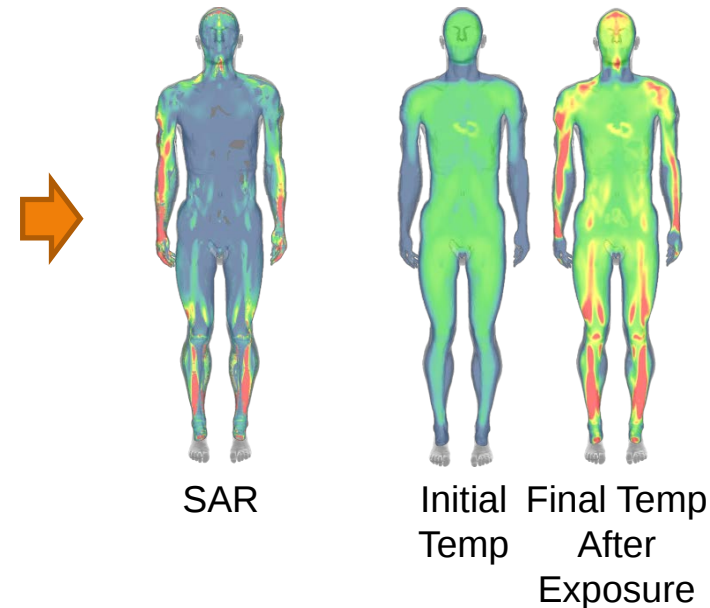


PIRE Methodology & Goals



Methods

- Review Literature
- Develop numerical and analytical solutions to predict thermal profiles from RF exposure
- Create models relating temperature to damage (also sensation/behaviour)
- Validate models with empirical observations



Goals

- Build real-time look-up tables
- Enable risk-based exposure standards
- Build RF injury knowledge base
- Create simulation components predicting RF exposure and damage



Current PIRE Studies



In vitro swine coupon – complete

- **Validates superficial thermal model predictions**
- **Relates Arrhenius burn model to observed burns**

Ex vivo human panniculus – data collection beginning soon

- **Dose required to produce burns**
- **Burn morphology**

In vivo swine – protocol approved

- **Dose required to produce burns**
- **Burn morphology**



Swine Coupon Experiment



Purpose:

- **Validate thermal predictions across a range of power levels using a shallow-penetrating frequency**
- **Collecting empirical data to derive temperature dependent properties**

Model Details:

- **Multi-Physics approach to RF Bioeffects:**
 - **Electromagnetics + ThermoDynamics + Bio Response**
- **Parameters are temperature dependent (viz., conduction, diffusivity, specific heat)***
- **Utilizes an Arrhenius damage formulation**

* Analytical Solution to Nonlinear Thermal Diffusion: Kirchoff Versus Cole-Hopf Transformations; Peter Vadasz, 2010; Journal of Heat Transfer



Swine Coupon Experiment



Experimental Conditions

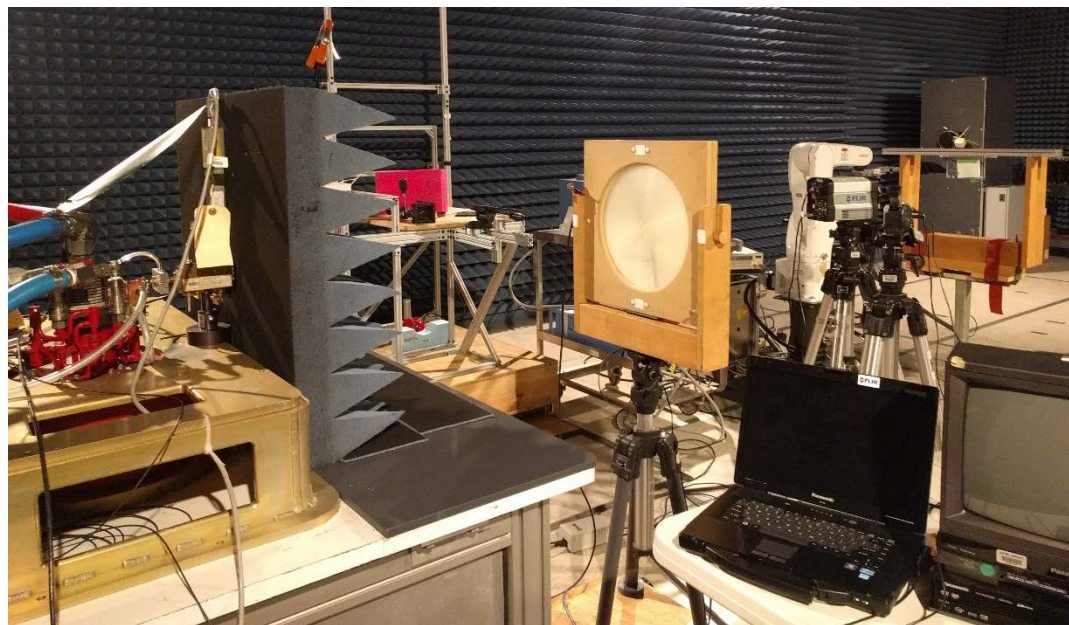
		Dose (J)				
		6	10	15	20	30
Power(W/cm2)	3					
	10					
	30					

Apparatus

- EHF transmitter

Experimental Procedures

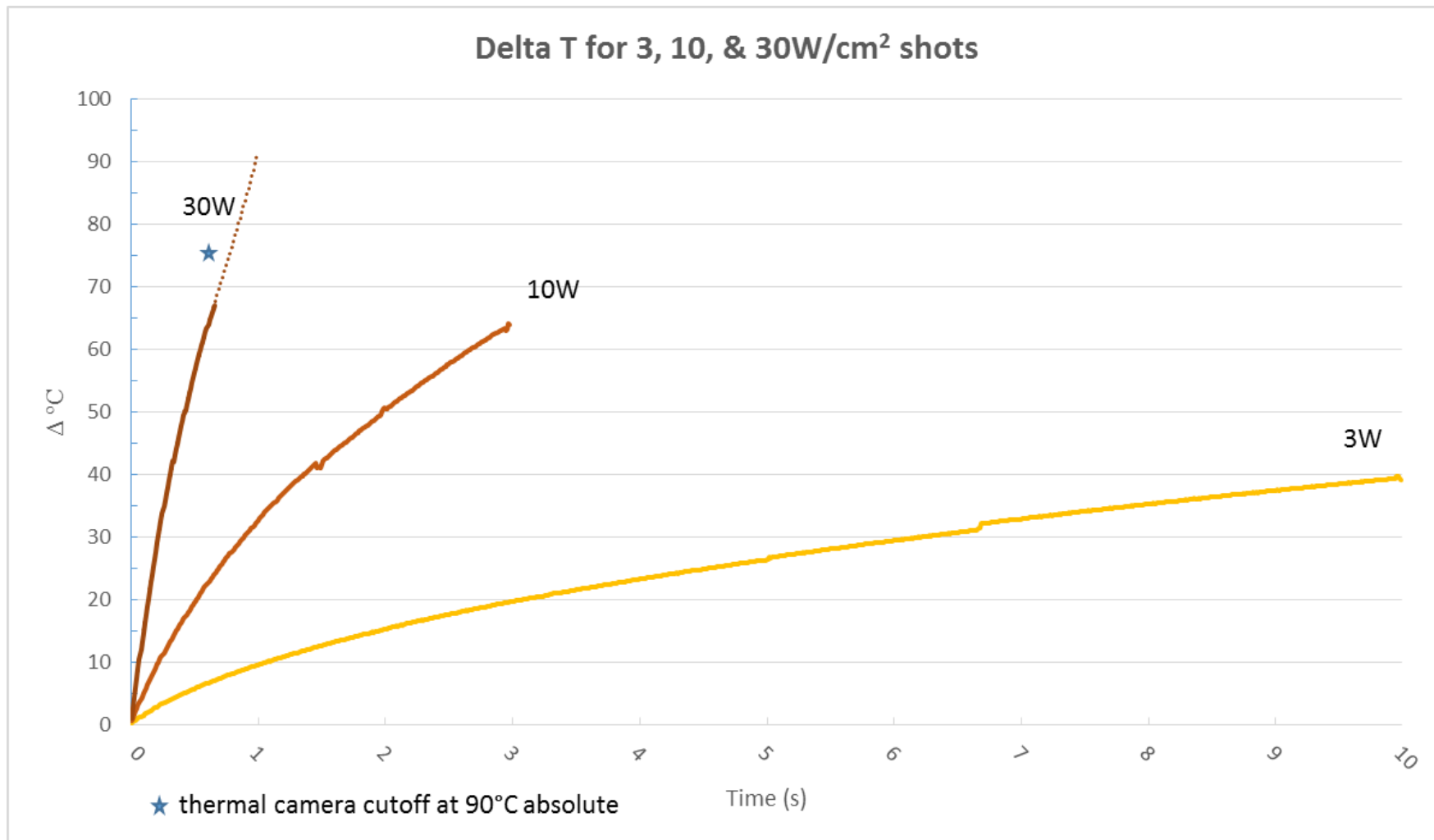
- Samples at room temperature
- Thermal imaging
- 4cm dia spot
- Histopathology





Swine Skin Coupon Study

Temperature Data



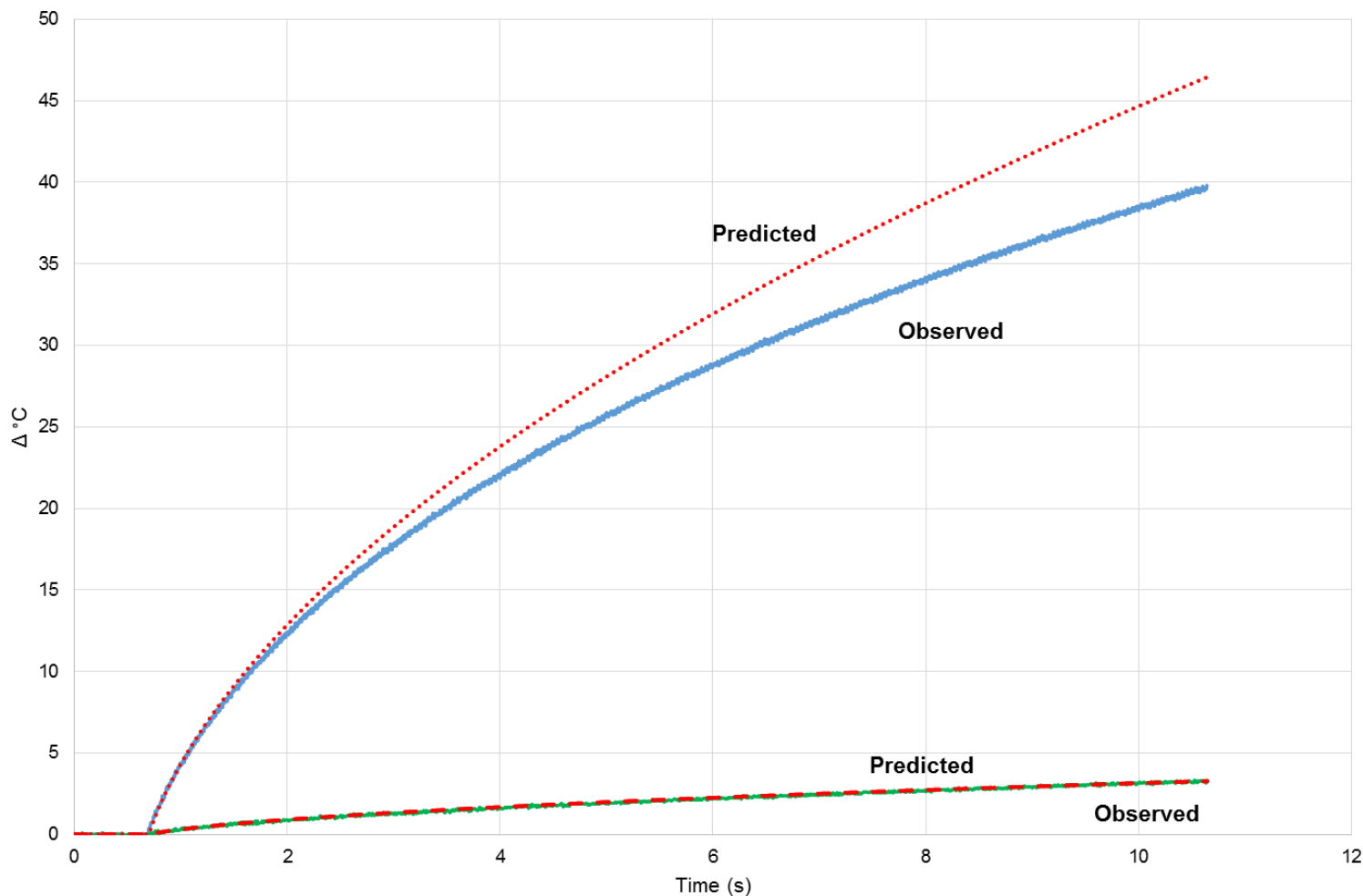


Swine Skin Coupon Study

Model Prediction (Static)

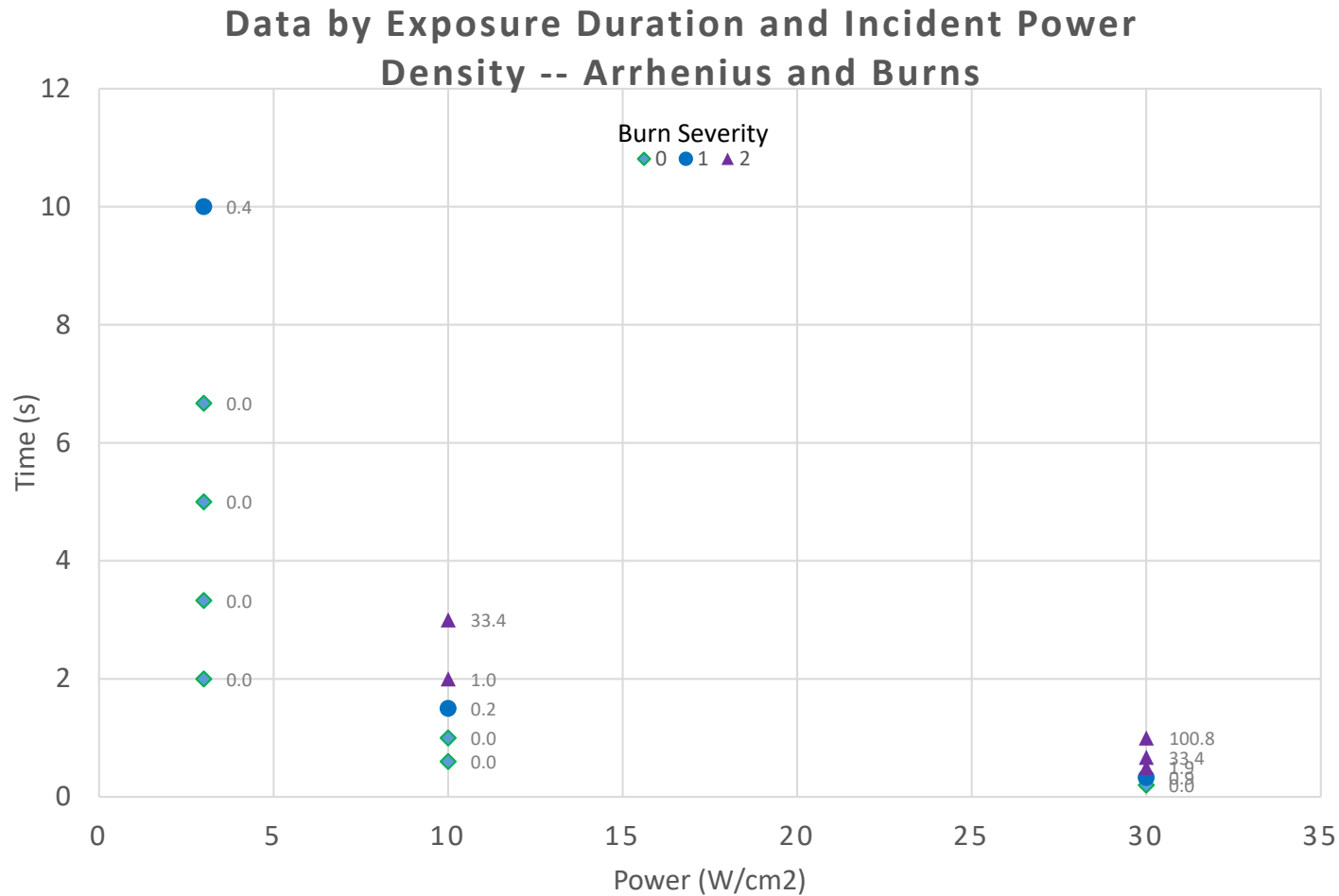


Predicted vs Observed Temperature:
Gaussian center and edge





Swine Skin Coupon Study Damage Metrics



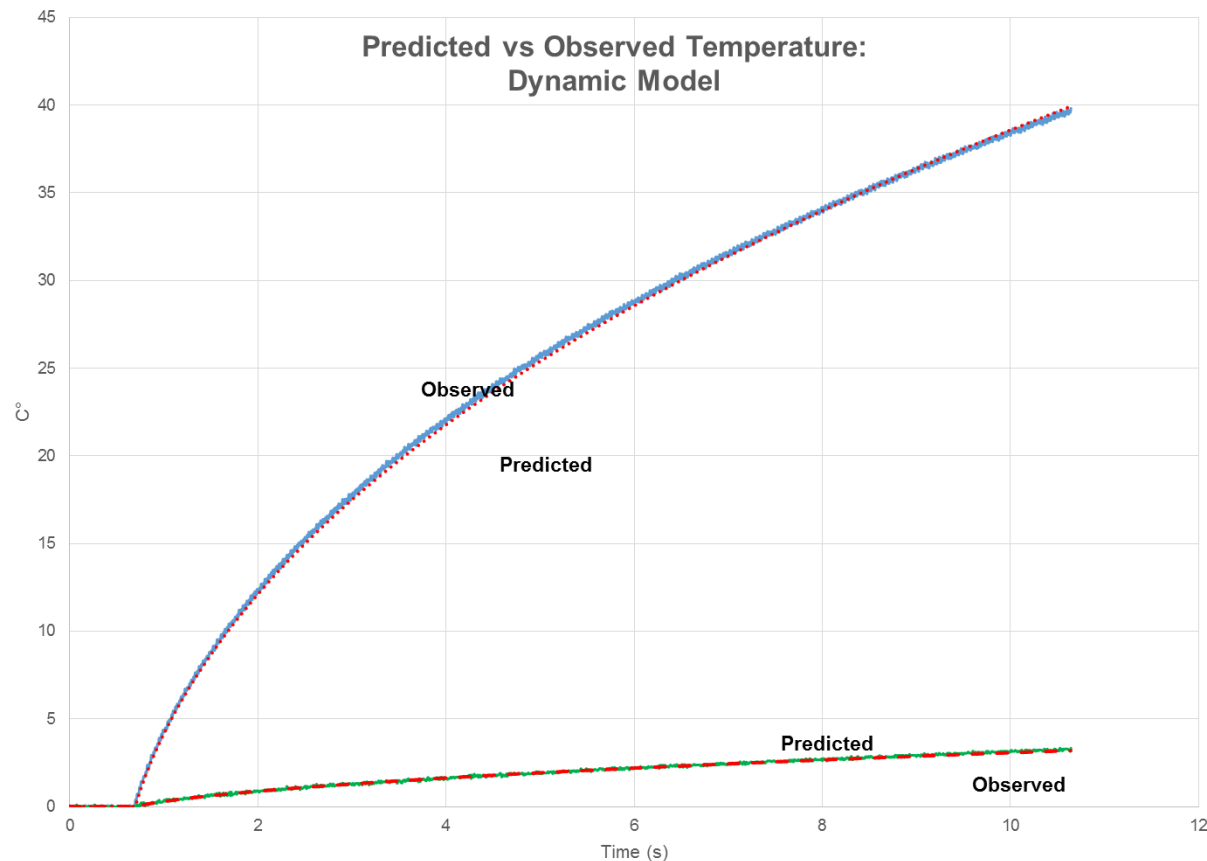
- Arrhenius predictions match histopathology score
- Dose required to produce damage is a function of incident power density - Agrees with Diller and Pearce, 1999; Issues in modeling thermal alterations in tissues; Ann NY Acad Sci



Swine Skin Coupon Study Results & Conclusions



- Static tissue property model fails to predict the thermal kinetics at higher temperatures
 - Tissue properties/conduction coefficient change as temperature increases
- A dynamic model was created to include temperature dependent parameters





Next Steps: Panniculus Study



Experimental Conditions

		EHF				SHF			
		Time(s)				Time(s)			
		5	10	15	20	5	10	15	20
Power(W/cm2)	3								
	30								

Apparatus

- SHF & EHF transmitters

Procedures

- Recent abdominoplasty
- Arterially perfused with whole blood
- Samples exposed at normal body temperature

Measures

- Histopathology
- Hydration





QUESTIONS

