



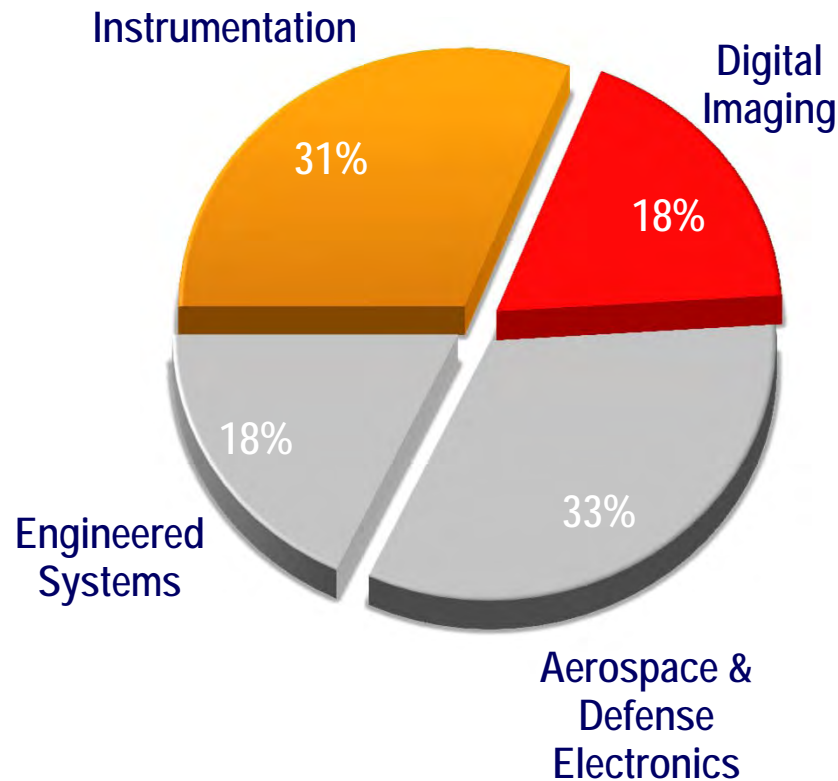
**TELEDYNE
TECHNOLOGIES**
I N C O R P O R A T E D

Robert Mehrabian

**Teledyne Oil & Gas Technology Day
November 16, 2011**



~\$2 Billion Revenue



Enabling Technologies for Industry

- ▶ Offshore energy exploration & production
- ▶ Marine science & technology
- ▶ Environmental monitoring
- ▶ Machine vision
- ▶ Information management
- ▶ Novel materials and electronics

Foundation for Continued Growth



- ▶ Technologies for challenging applications
 - ◆ Extreme environment materials and interconnect products
 - ◆ Acoustic sensors and marine survey systems
 - ◆ Chemical and physical property monitoring
 - ◆ Custom imaging sensors, cameras and software
 - ◆ Information management for intelligent decision making
- ▶ Strong base of research and development
 - ◆ Internal R&D of ~\$100M
 - ◆ >\$100M of additional relevant funded R&D
 - ◆ Applying government sponsored research to commercial applications
- ▶ Highly technical workforce

Electromagnetic and Acoustic Waves

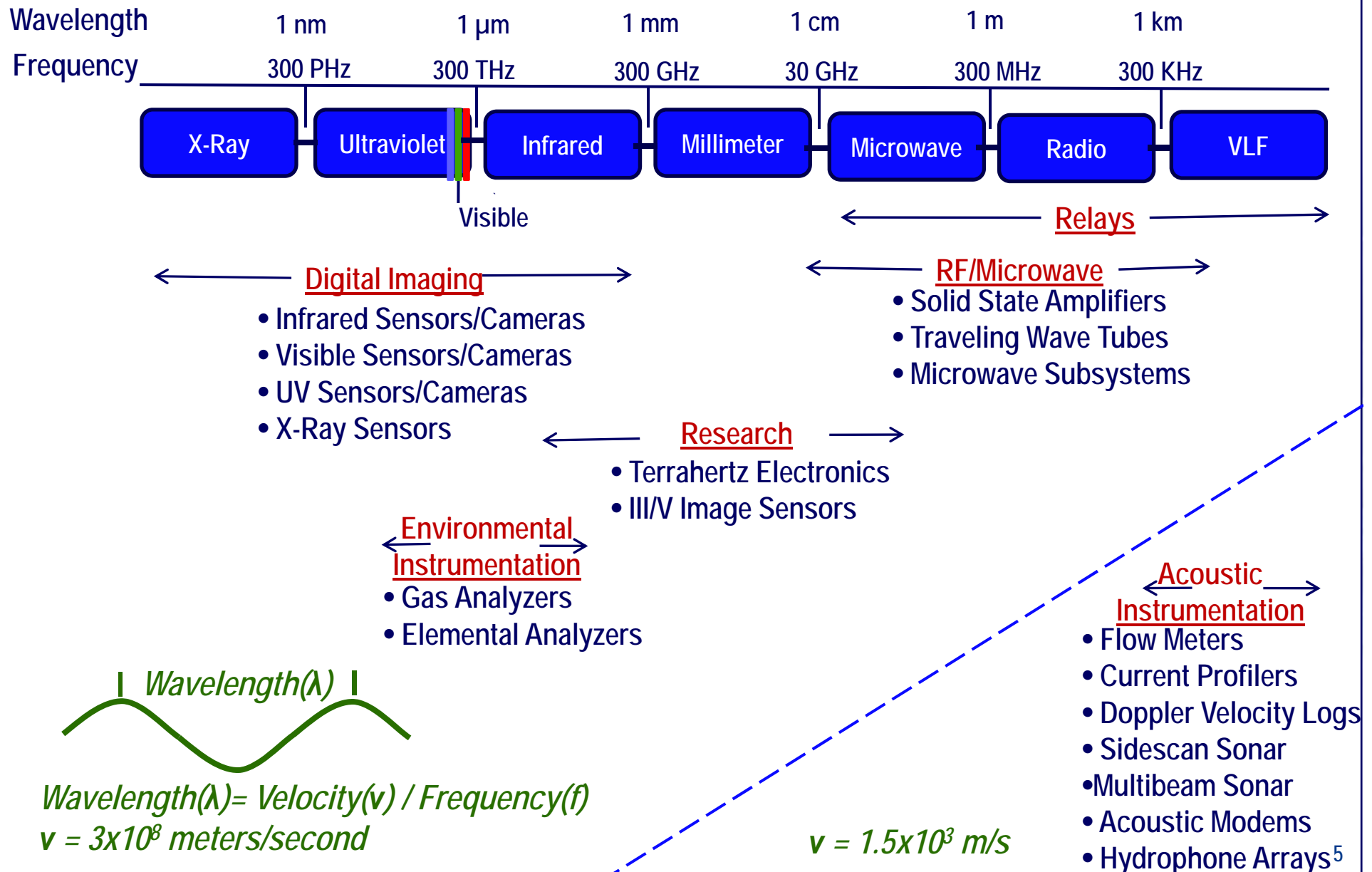


Wavelength (λ) (meters)

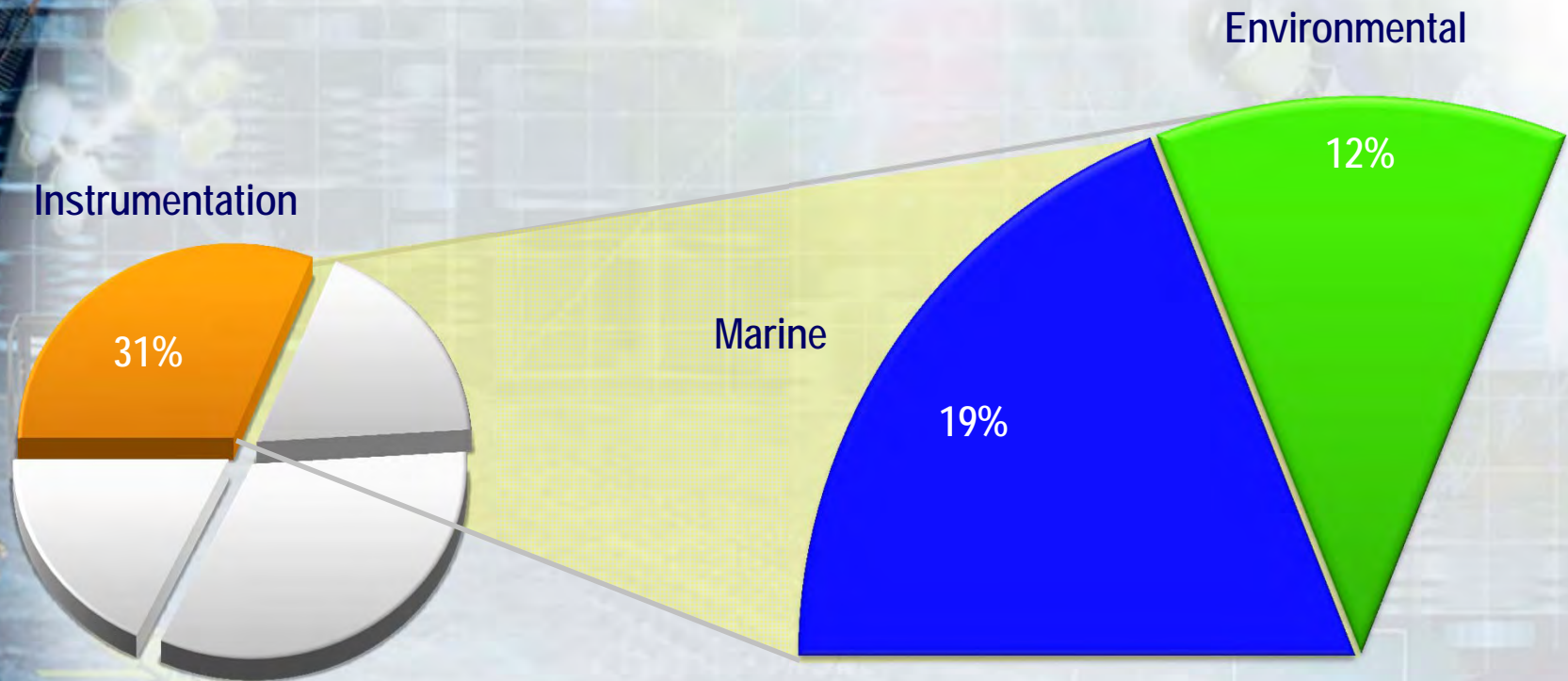
$$\text{Wavelength } (\lambda) = \frac{\text{Velocity } (v)}{\text{Frequency } (f)}$$

Shorter Wavelength = Higher Frequency

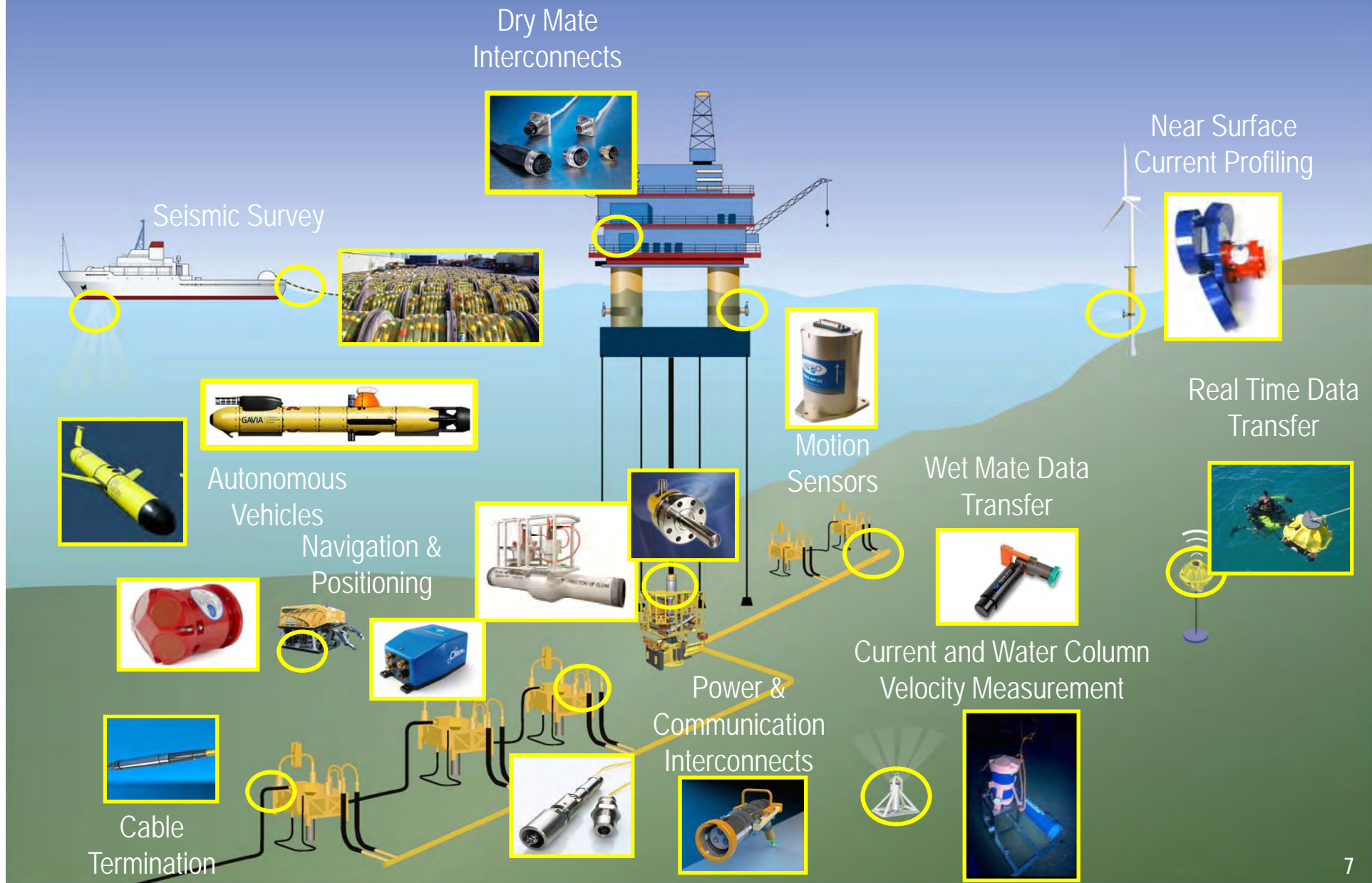
The Full Spectrum of Teledyne's Technology



Teledyne Instrumentation



Teledyne Marine



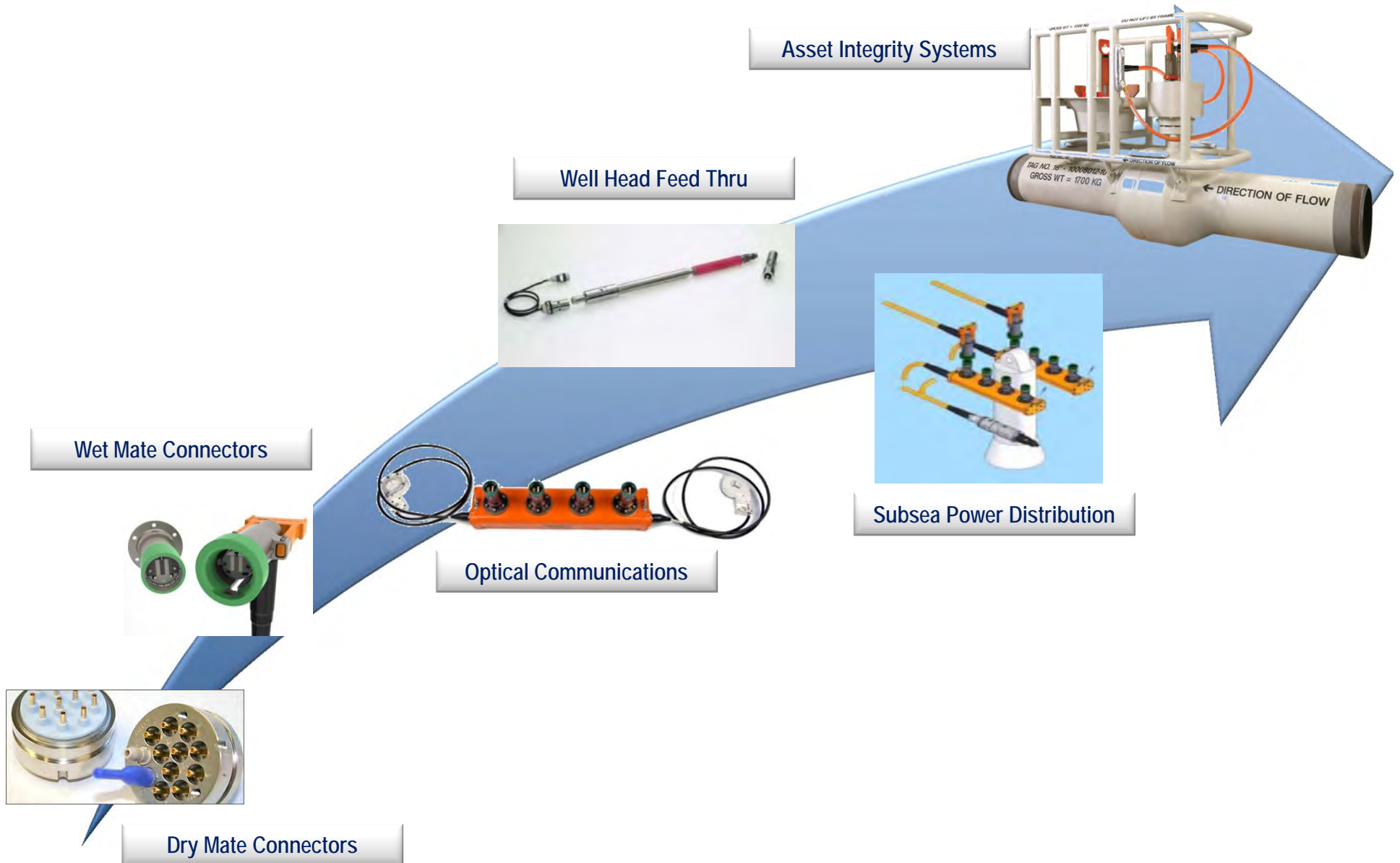
Robust Pipeline of New Marine Technologies



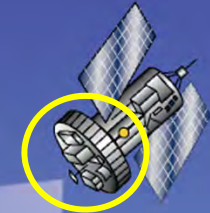
- ▶ New sensors and interconnect systems for deepwater oil and gas production
- ▶ Reservoir monitoring systems
- ▶ Unmanned underwater vehicles
- ▶ Higher performance hydrographic survey systems
- ▶ Subsea materials reliability database
- ▶ High power ceramic penetrators



Product Progression & Increased Value to Customers



Teledyne Environmental Monitoring



Remote Sensing

Continuous Emission Monitoring



Gas Leak Detection

Combustion Efficiency



Oil in Water Analyzers



Power Plant



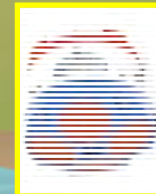
Ambient Air Monitoring



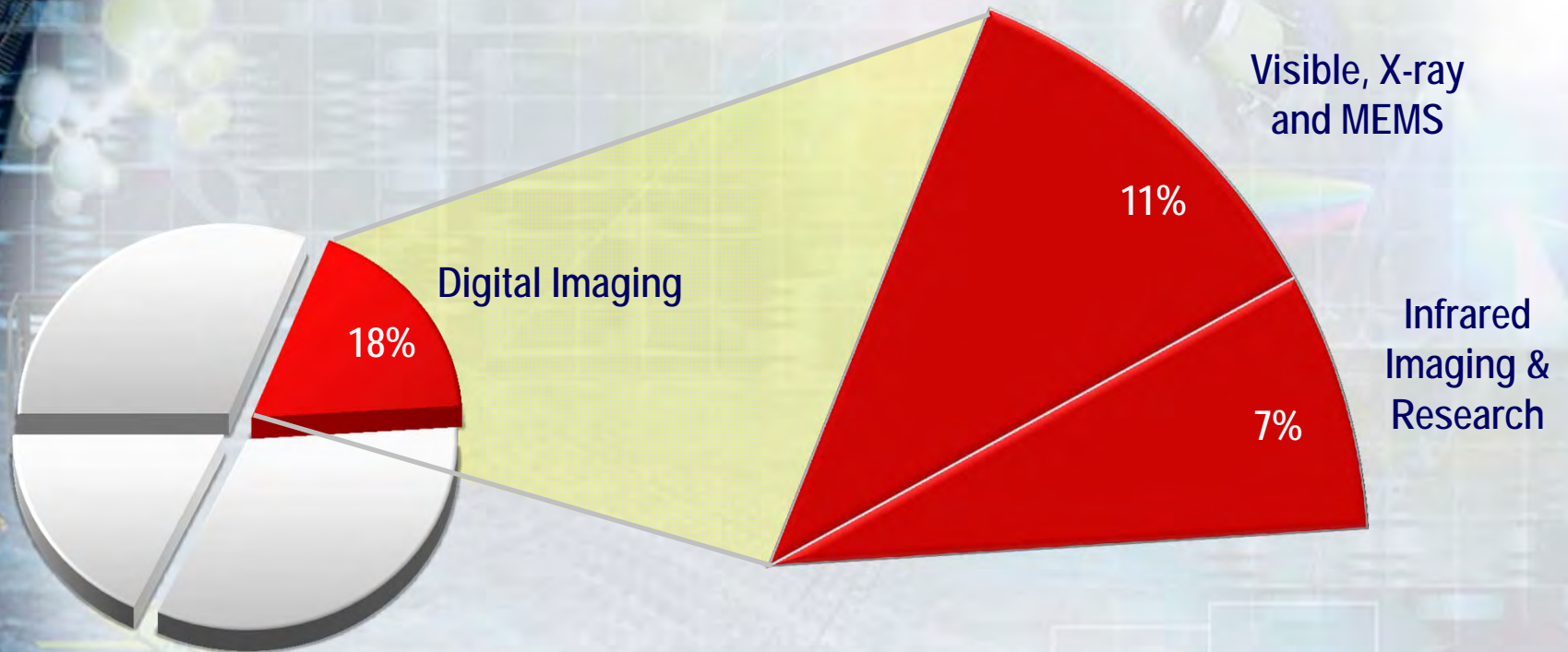
Water Sampling



Flow Measurement



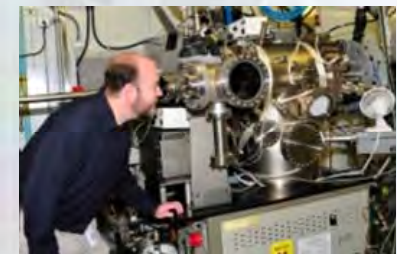
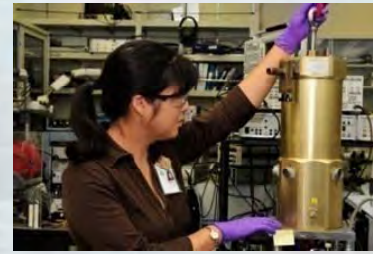
Teledyne Digital Imaging



Teledyne Research: A Unique Asset



- ▶ One of a very few remaining corporate R&D labs – established in 1962

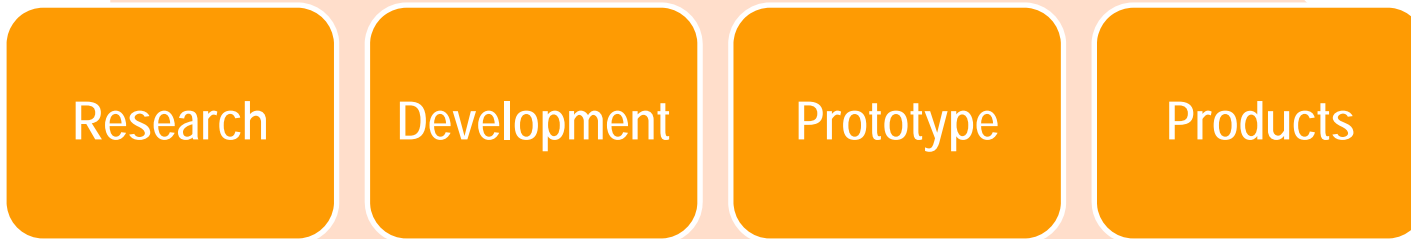


- ▶ 316 technical staff ~ 35% PhDs
- ▶ 278 active patents

- ▶ **Teledyne's Research Business Model**

- ◆ Government funding supports early stages of novel, high risk technology development
- ◆ Researchers work jointly with Teledyne's operating business to adapt technology to customer applications
- ◆ Proprietary research projects directly for industry customers

Capturing Value from Teledyne Research



Core R&D Disciplines – Selected Examples



Materials

- ▶ Extreme environment
- ▶ Anti-biofouling
- ▶ Ultrafiltration & desalination
- ▶ Thermal management



Optics

- ▶ Polarization imaging
- ▶ Fiber optic sensors
- ▶ Precision 3-D positioning



Information Sciences

- ▶ Image processing
- ▶ Augmented reality
- ▶ Autonomous systems



Electronics

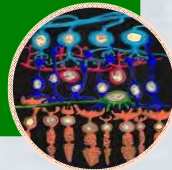
- ▶ Chip-scale atomic clock
- ▶ High power electronics
- ▶ MEMS sensors



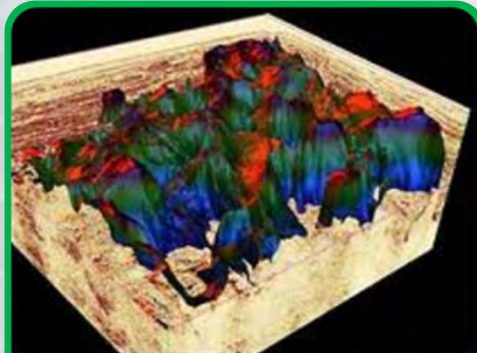
Useful Information from Digital Images



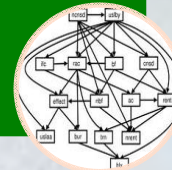
Signal and Image Processing



- Biologically inspired image enhancement
- Basic science of recognition and classification



Data to Actionable Information



- Underwater image processing
- Acoustic processing
- Sensor signal conditioning



Human Computer Interaction

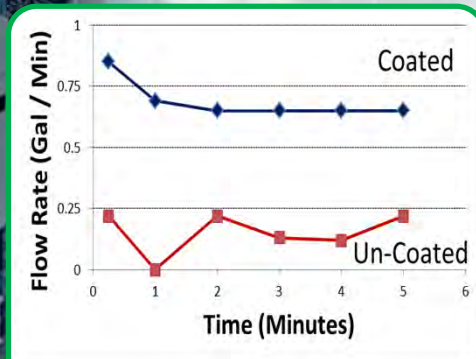


- ROV operations
- Maintenance and repair
- Training
- Remote expert guidance

Materials: Anti-fouling and Ultra Filtration



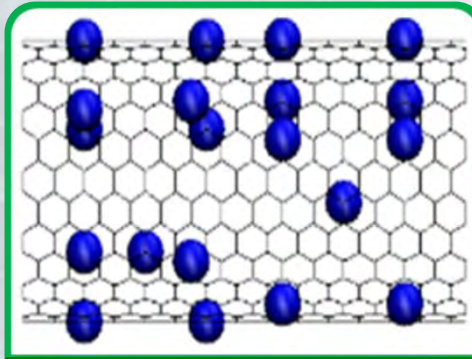
- ▶ Teledyne Scientific's Materials Scientists are synthesizing new materials for the extreme environments in Oil and Gas



Antifouling Coatings



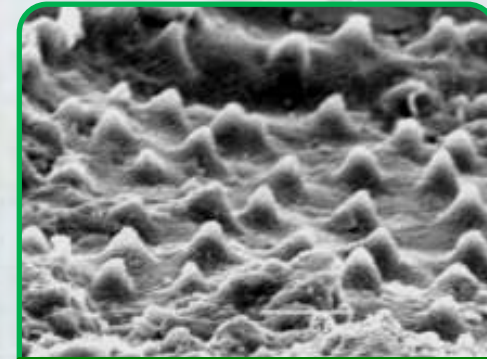
- Superhydrophilic coatings
- Proprietary nanoscale material synthesis
- Extend life, reduce energy and maintenance costs



Carbon Nanotube RO Membranes



- High Flux RO filter stages
- Size-selective carbon nanotube membranes
- Energy recovery and reuse
- Methodology applicable to Oil and Water treatment and separation



Boundary Layer Disruption

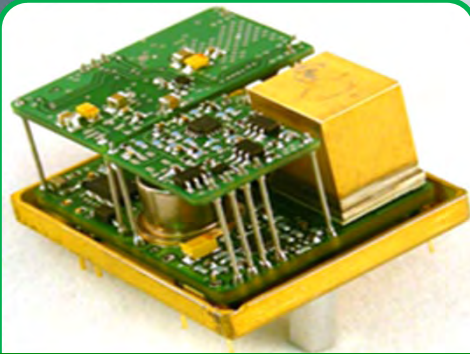


- Surface modification
- Reduced foulant aggregation
- Longer operational lifetime

Electronics: Positioning, Navigation & Timing



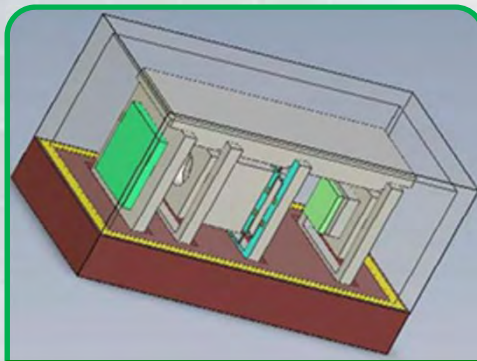
- ▶ Miniature technologies for GPS-denied environments
- ▶ Scientific and DALSA: MEMS R&D and Low Cost manufacturing



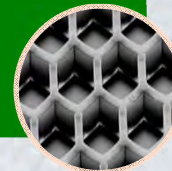
Chip-scale atomic clocks



- Initial demonstration of new products at Scientific: CSAC, Gyro, tunable IR detectors, miniature sensors



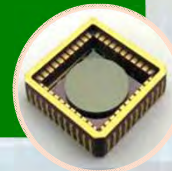
Design for manufacturing



- Design center at Scientific into MEMS production facility
- Collaboration with Teledyne and industry for product development



Production Volumes at Teledyne DALSA



- Production at World's most advanced MEMS Foundry at Teledyne DALSA

Thermal and Flow Physics



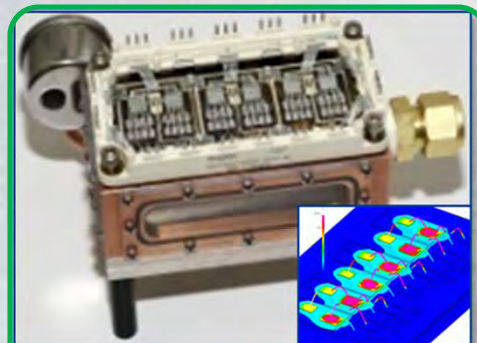
Thermal Management and Flow Control



Materials for Extreme Environments



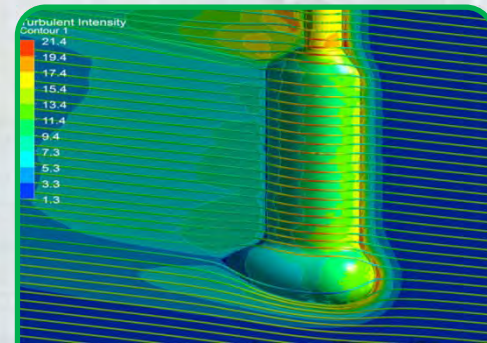
- Strong Ceramic fiber architectures
- Combined thermal & mechanical load
- Actuated, shape changing CMC panels



High Heat Flux Cooling & Thermal Interface Materials



- Microfluidics and surface science
- Phase Change Materials
- Thermal Ground Planes
- Novel Heat Pipe Designs



Modeling & Analysis

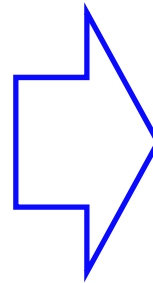
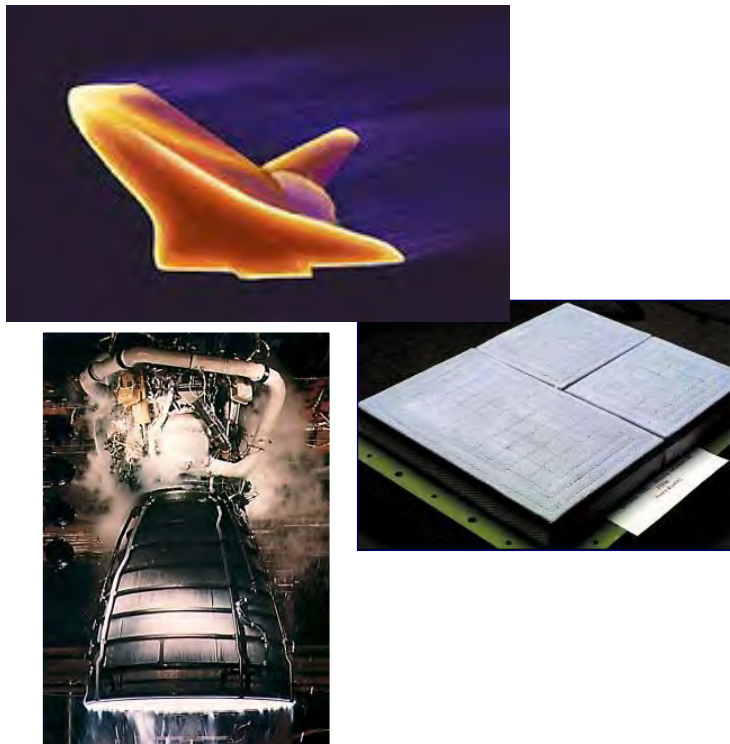


- CFD, CSD, and CEM
- Multi-physics simulation
- Multi-scale modeling, Reduced models
- Meta material design

Materials: Hi-Rel Experience for the New Deepwater Frontier



Leveraging Decades of Government Investment in Materials Research



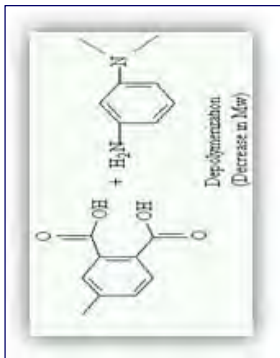
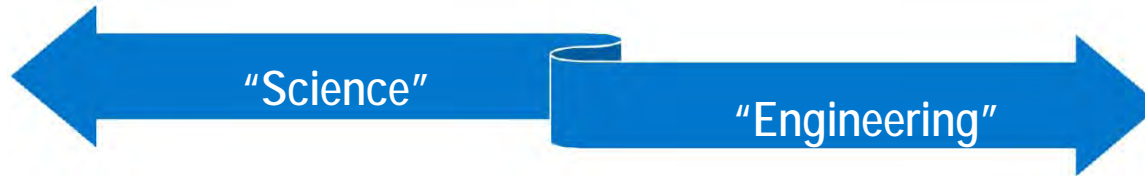
▸ Challenges in Space

- ◆ Extreme temperatures
- ◆ Long lifetime
- ◆ Repair is not an option
- ◆ Corrosive conditions
- ◆ Structural load
- ◆ Process Chain Traceability

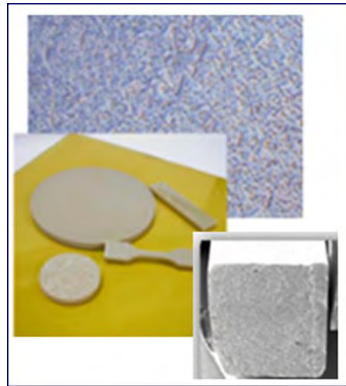
▸ Challenges in Deepwater

- ◆ Extreme temperatures
- ◆ Long lifetime
- ◆ Repair is impractical
- ◆ Corrosive conditions
- ◆ Structural load
- ◆ Extreme pressures

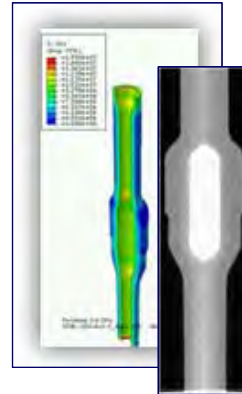
Materials: Research for High Reliability



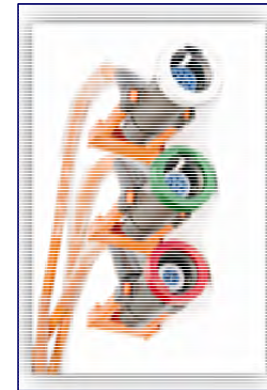
Physics



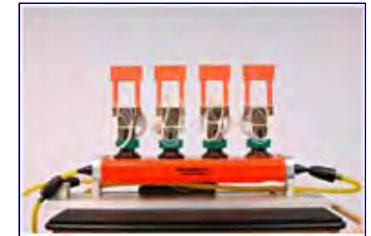
Materials Science & Engineering



Components



Products



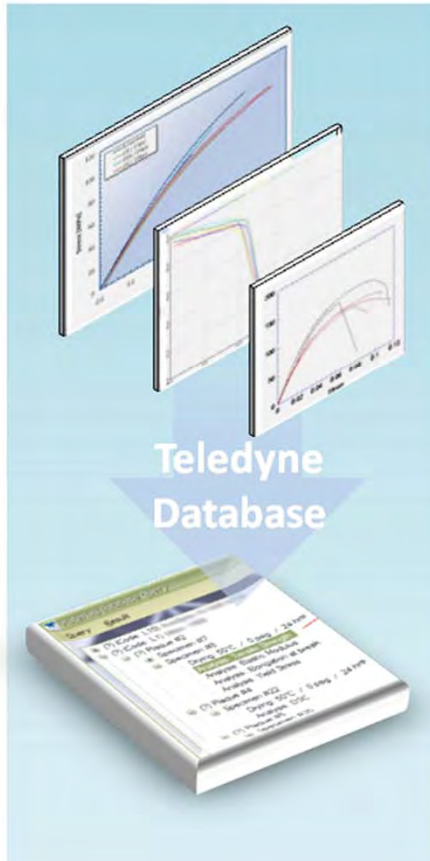
Systems



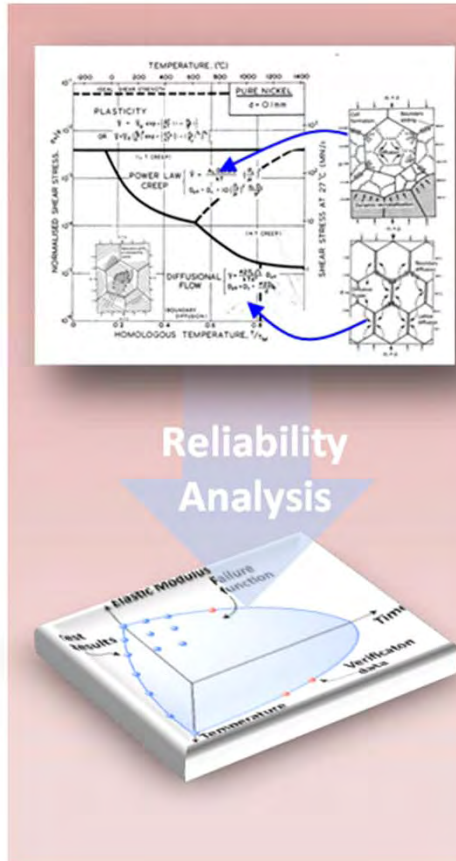
Materials: Oil and Gas Reliability Database



Fully Searchable
Proprietary Database



Identify Degradation
Mechanisms



Materials Selection to
End-of-Life Properties

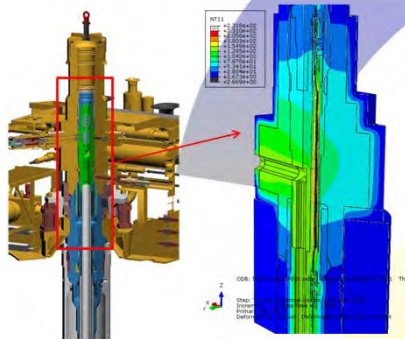


- ▶ Developed test methods for multiple stress conditions
- ▶ Determined critical life-limiting degradation mechanisms

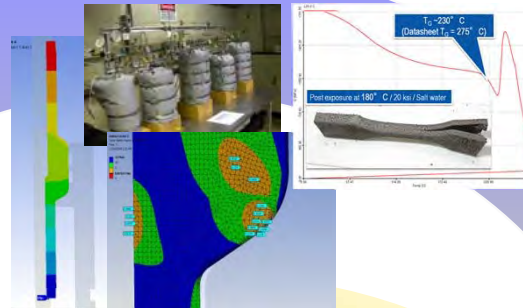
Materials: Applying Science to Product Development



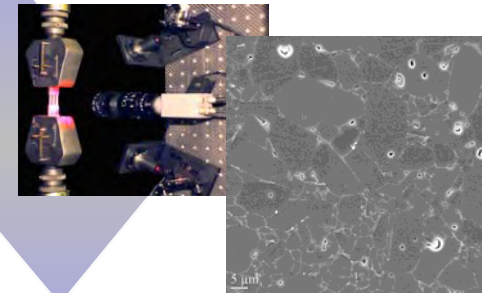
Work with *Customer* to Define Component Requirements



Materials Selection
Component Analysis



Qualification



Customer Appreciation



Subsea
Pump HP
Connector



New Product
Launch



Teledyne Partnership Opportunities



Continue to provide highly engineered, extremely reliable products to the Offshore Oil & Gas Market

Team with Oil & Gas Customers and Clients to solve complex problems in the New Deepsea Frontier:

Leverage 50 years of R&D experience in other fields to address key fundamental problems faced by the Oil & Gas Industry

Leverage the breadth of Teledyne's R&D portfolio

Leverage Teledyne's commitment to invest internally in strategic technology areas

Transition R&D to new Teledyne Oil & Gas products

Generate IP for our customers and their clients to develop their next generation products and systems