

Development of a Joule-Thomson Micro Compressor



LOCKHEED MARTIN
Advanced Technology Center

LOCKHEED MARTIN
*Missiles and Fire Control
Santa Barbara Focalplane*

Patrick Champagne

J. Olson, T. Nast, E. Roth, A. Collaco, G. Kaldas

Elna Saito, Vince Loung

Motivation

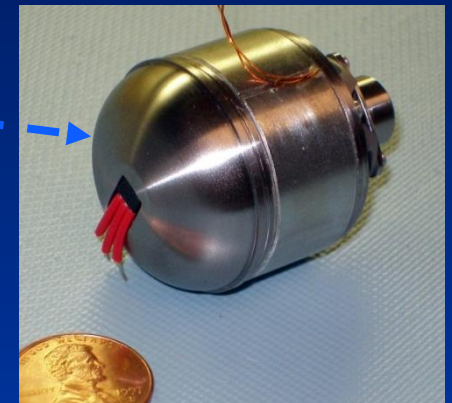
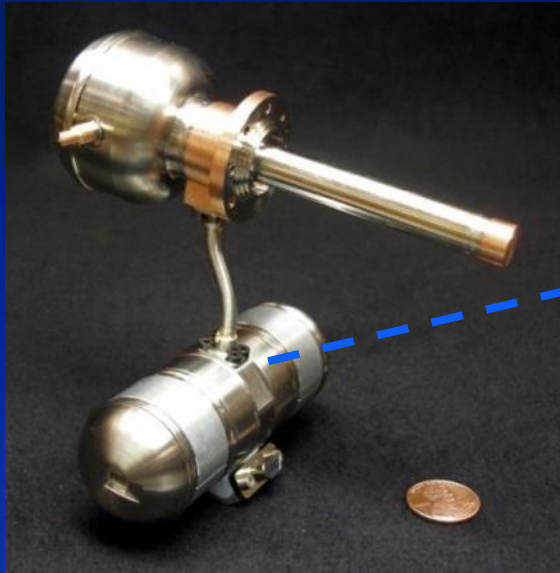


Utilize Pulse Tube Micro Compressor technology to develop a J-T compressor

- Retain: high reliability and low cost
 - Utilize space-quality compressor technology
 - Common parts/processes with existing Micro Compressor
- Retain: small size and weight
 - Based on mature Pulse Tube Micro Cryocooler
 - CubeSat compatible
- Add: DC flow rectified output
 - Able to power J-T cold heads
 - Adaptable to pumped cooling loop applications

Lockheed Martin Microcryocooler

Introduced in 2013



Microcryocooler

Coaxial pulse tube

Split cooler configuration

Long lifetime / High reliability

Low production costs

Micro Compressor

Length = 90 mm

Diameter = 32 mm

Mass = 190 g

Motor Module

Flexure bearing

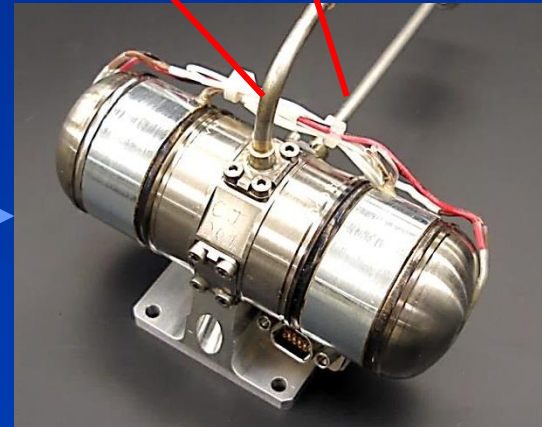
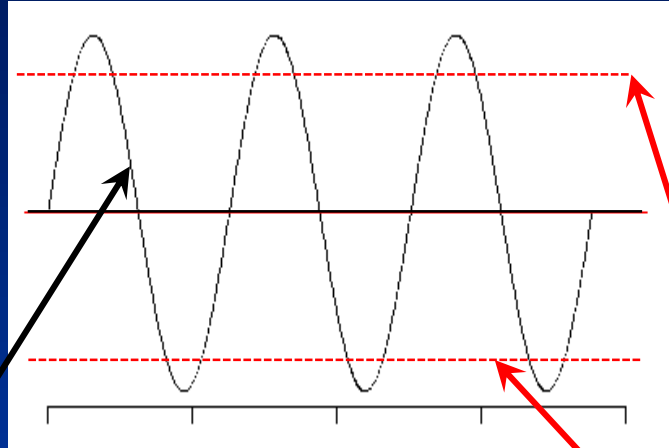
Clearance seal

Moving magnet

Linear motor

AC Pulse to DC Flow

Challenge: Pressure rectification

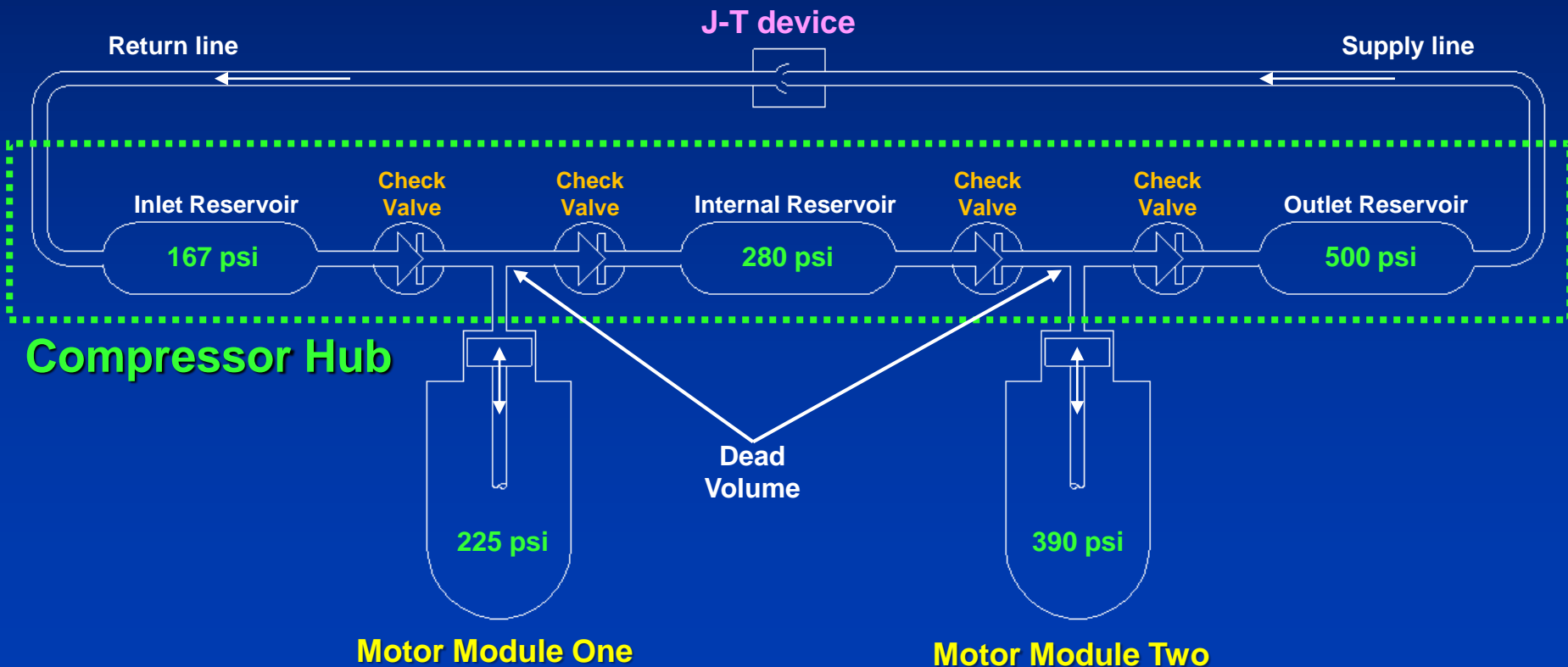


Schematic of 2-Stage Pump

Compression spaces separated and put in series

Each piston is equipped with a set of in/out check valves

Design pressure ratio = 3:1 (500 psi output, 167 psi input)



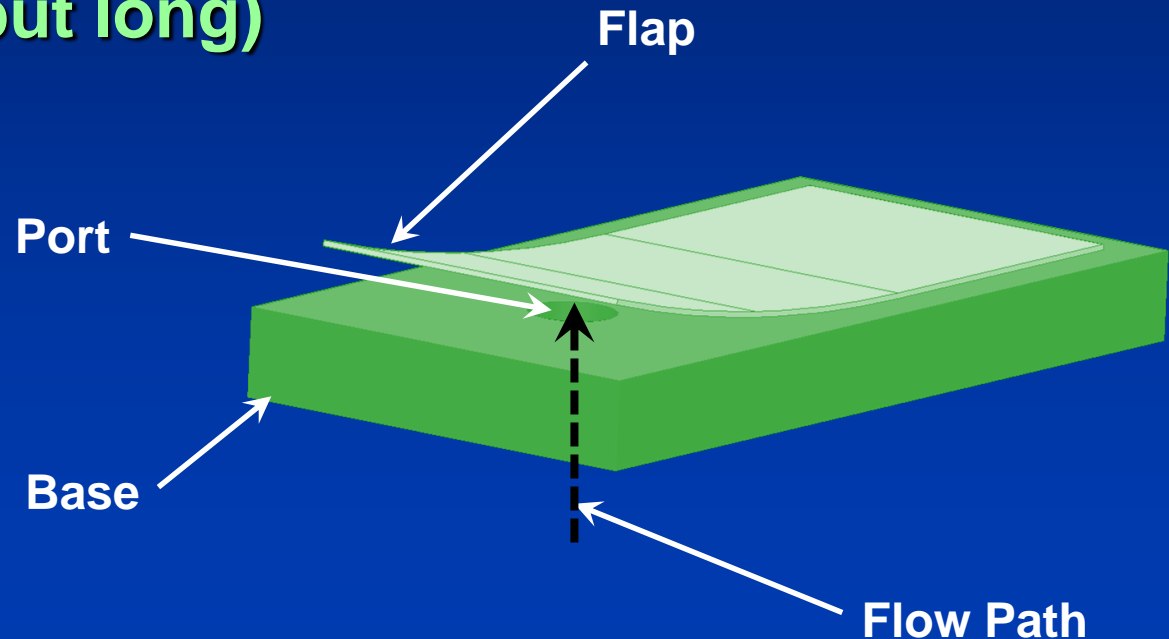
Flat Flap Check Valve

Simple: One moving part

Reliable: Self actuating

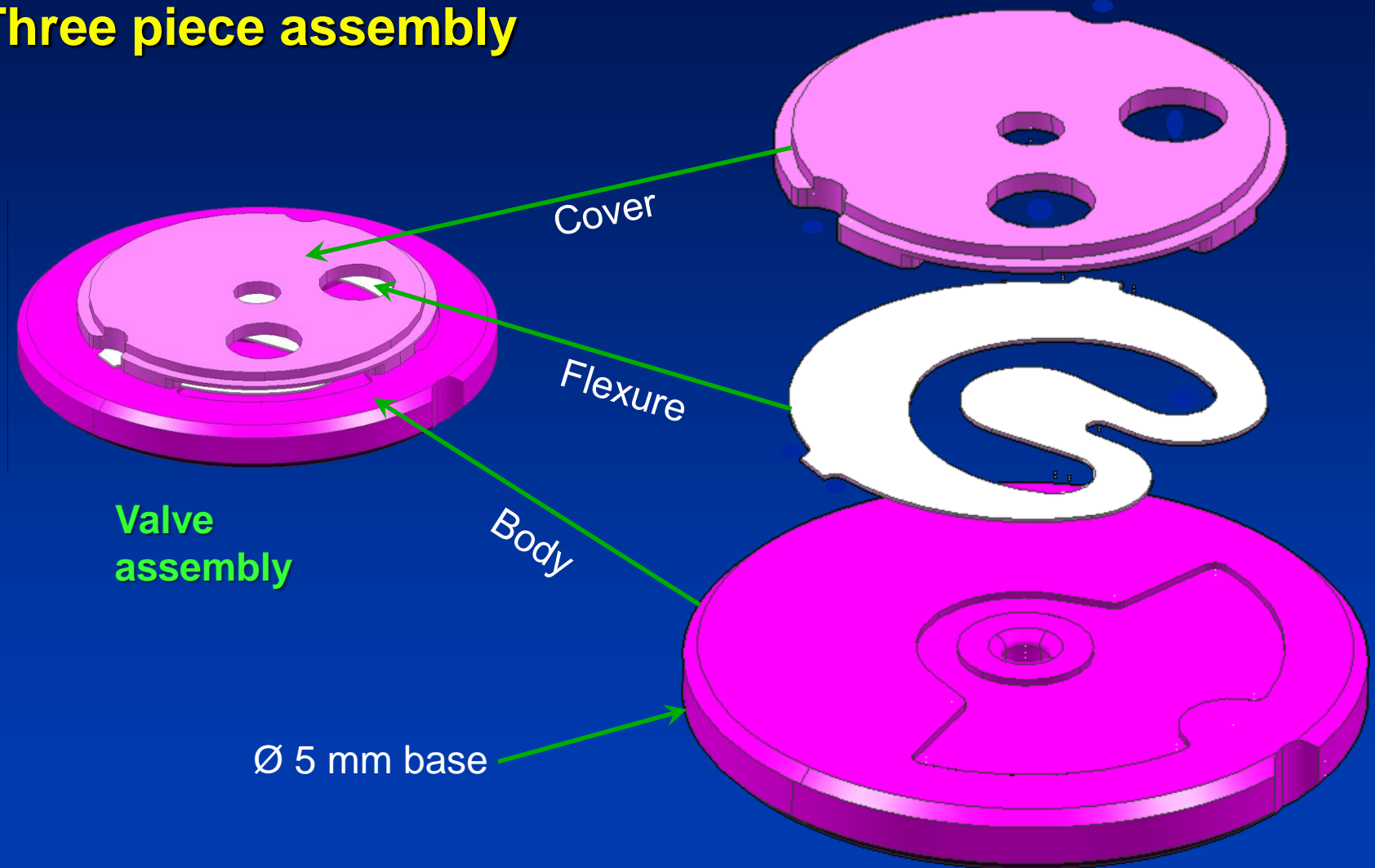
Low cost: Minimal machining

Small: Thin (but long)



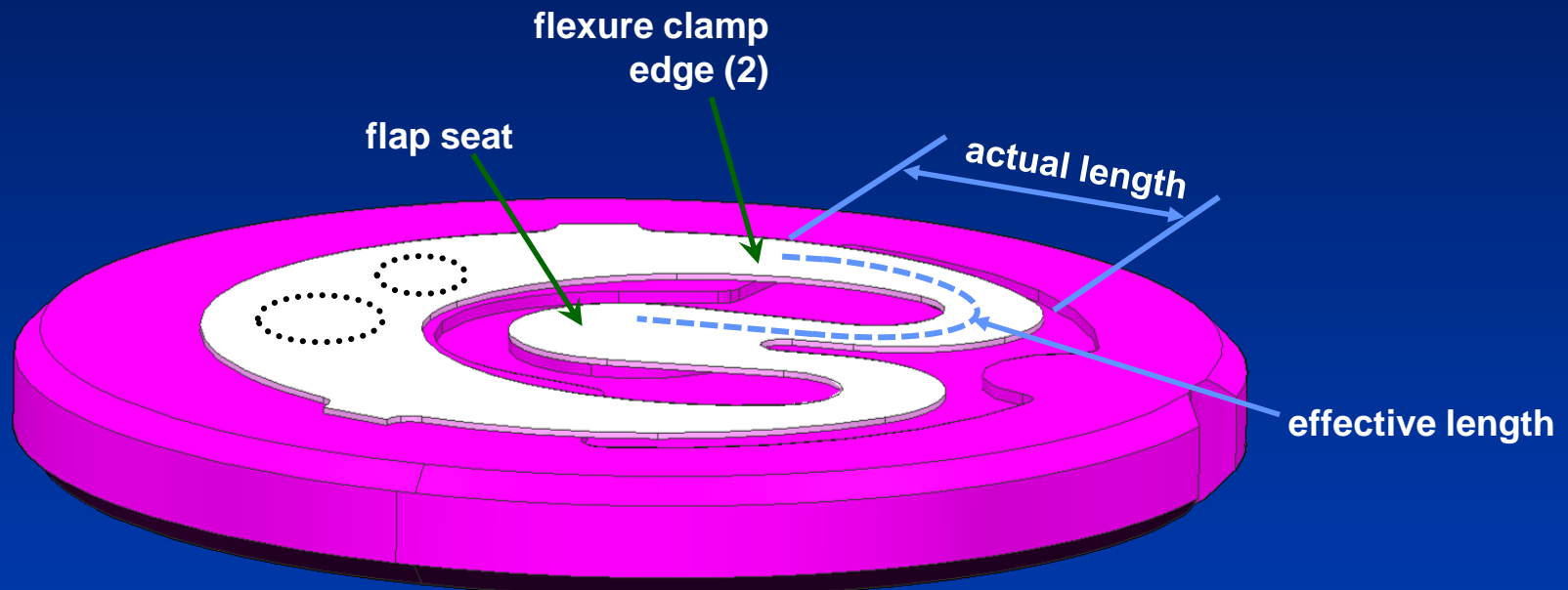
Micro Check Valve

Three piece assembly



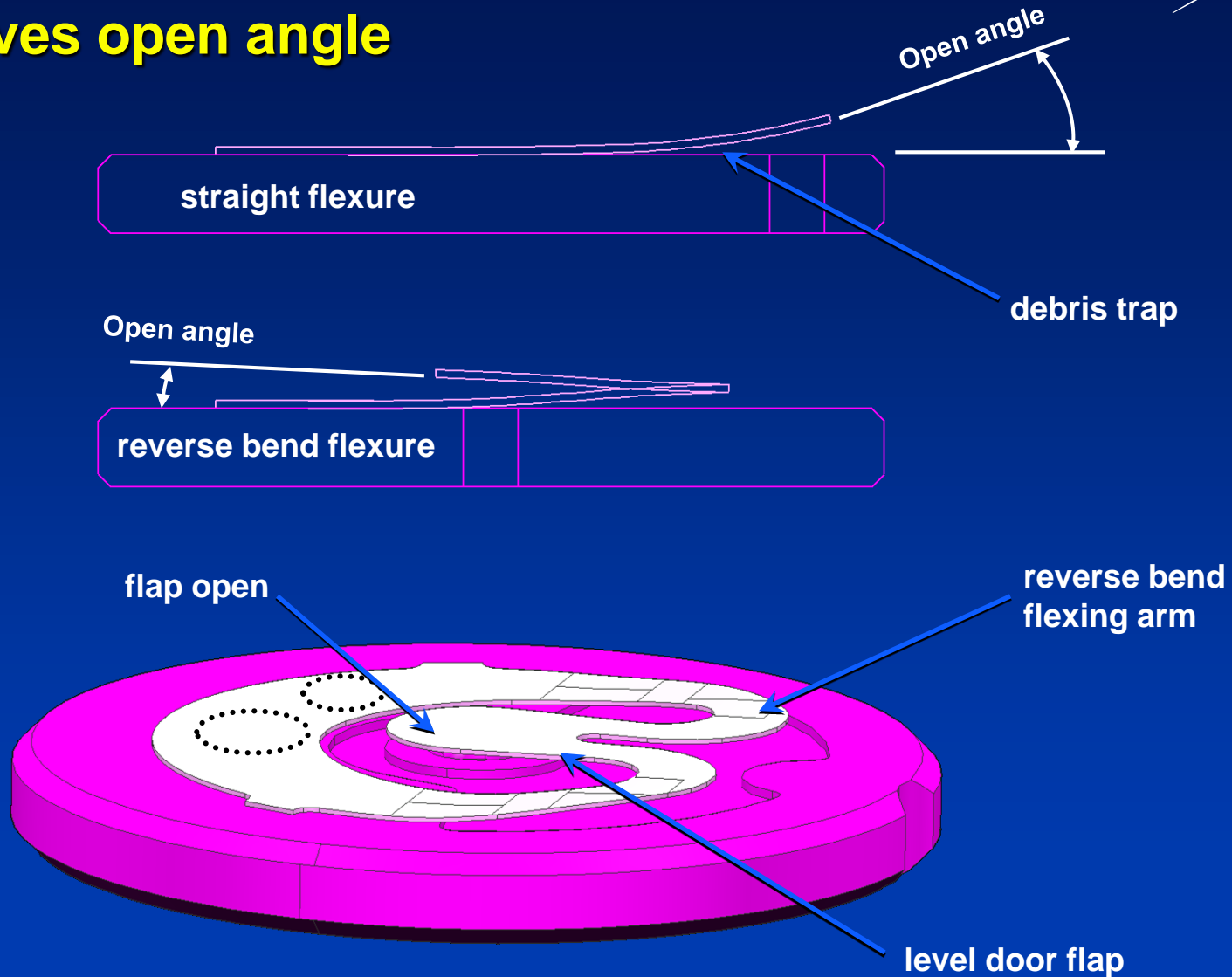
Reverse Bend Flexure

Reduces overall length/size



Reverse Bend Flexure

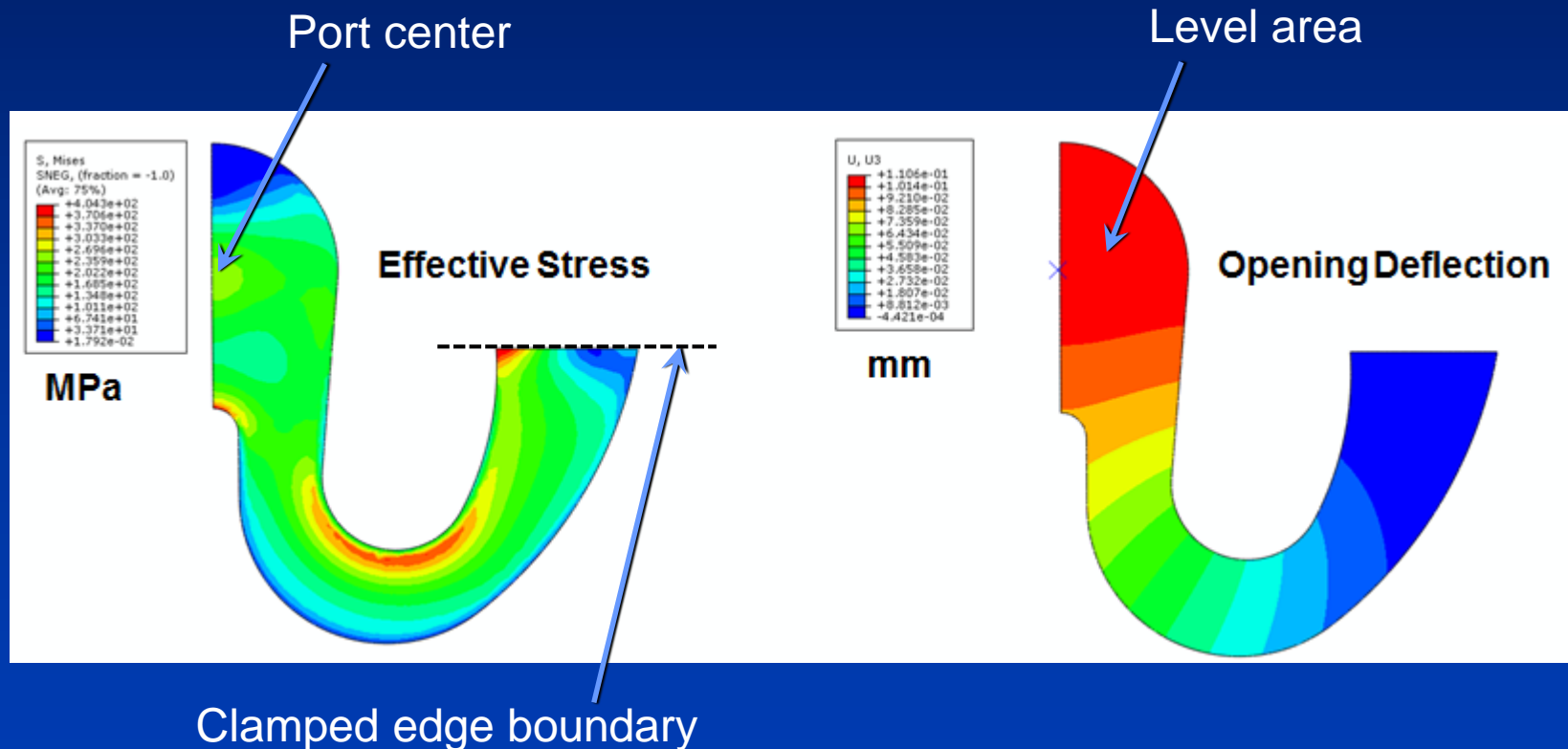
Improves open angle



Flap Analysis

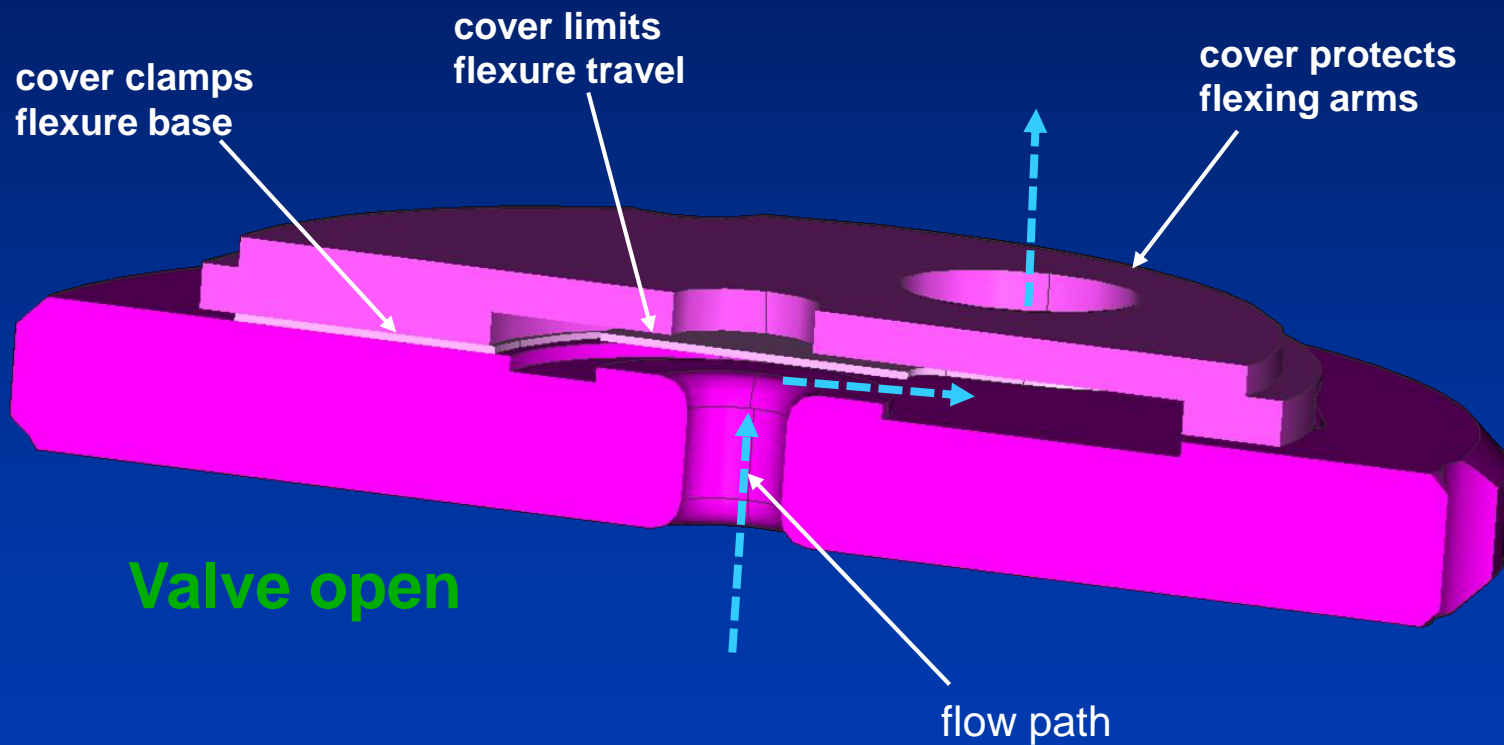
Stress: below ultimate fatigue limit

Deflection: full flow at port opening

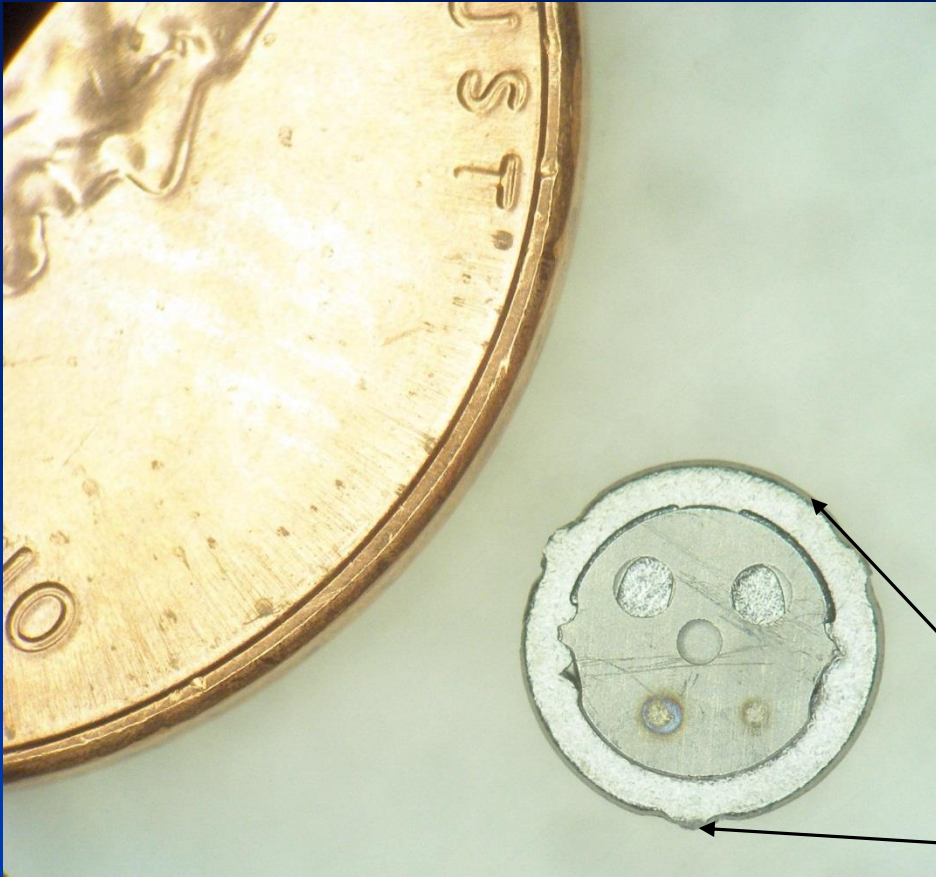
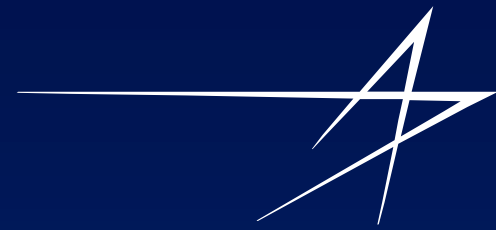


Valve Cross Section

Multi function cover

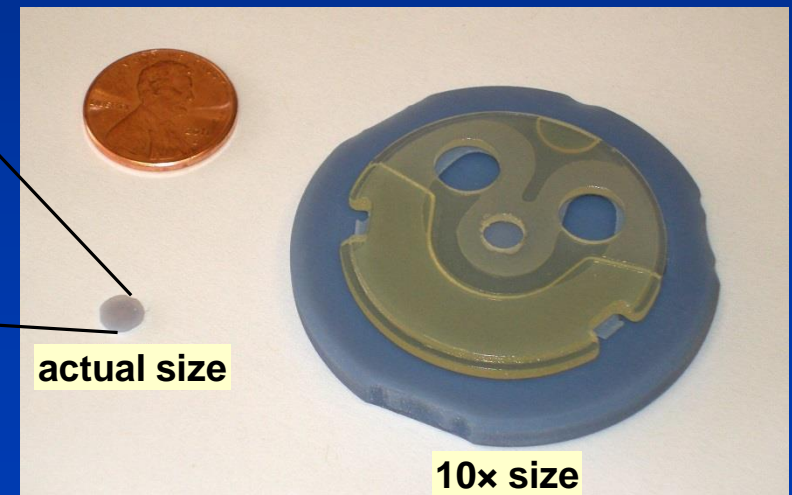


Check Valve Fabrication



Completed prototype

Plastic model



Check Valve Fabrication

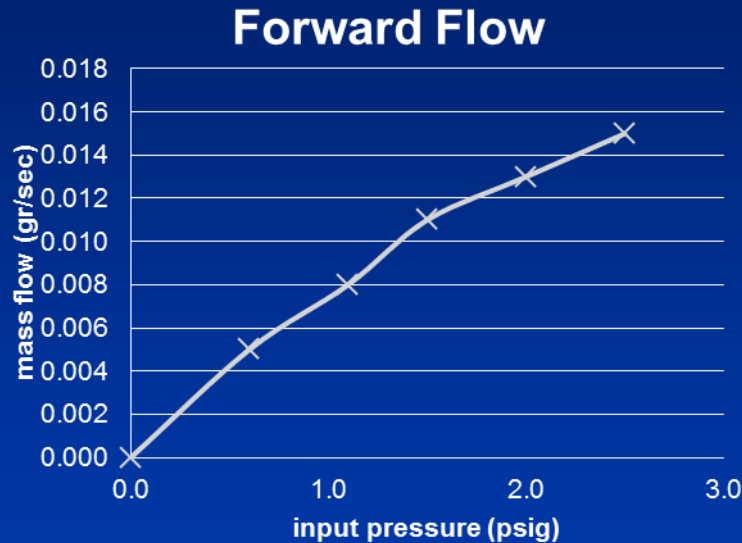
Carrier strips reduce component handling



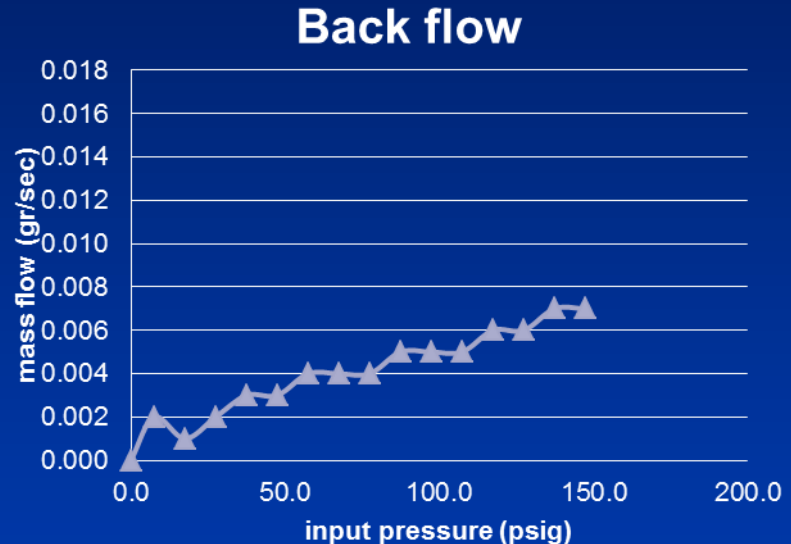
Measured Valve Operation

Single valve under static pressure

Demonstrated forward to reverse flow ratio of 200 to 1



Crack open pressure
measurable flow starts at
less than 1 psi



Survival pressure
valve undamaged by 250 psi
back pressure

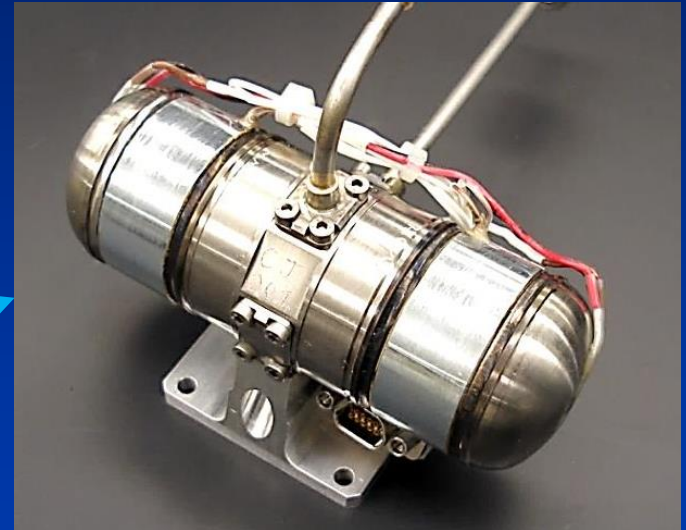


Check Valve Integration

Challenge: 2 pistons + 4 valves

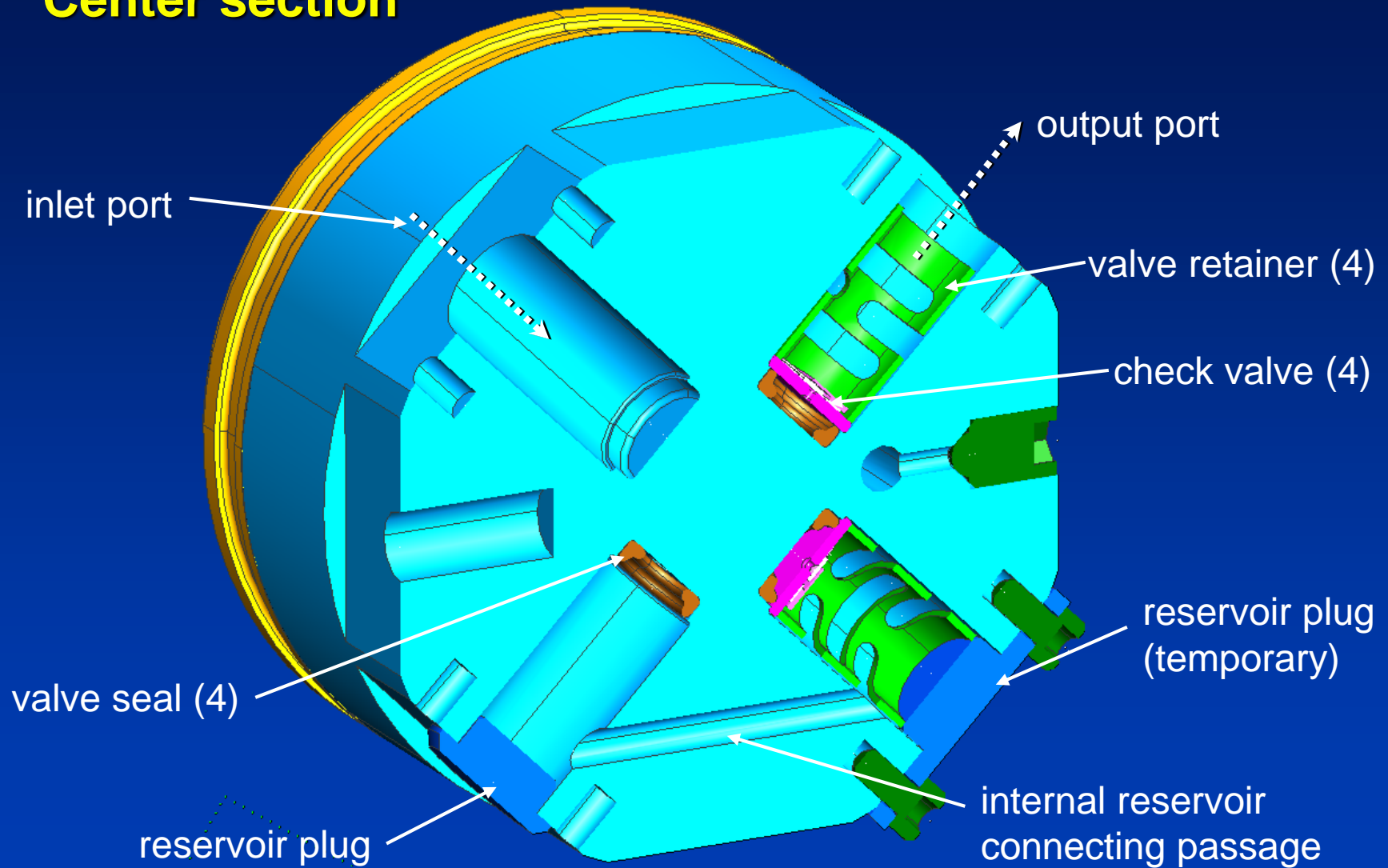


4x (not to scale)



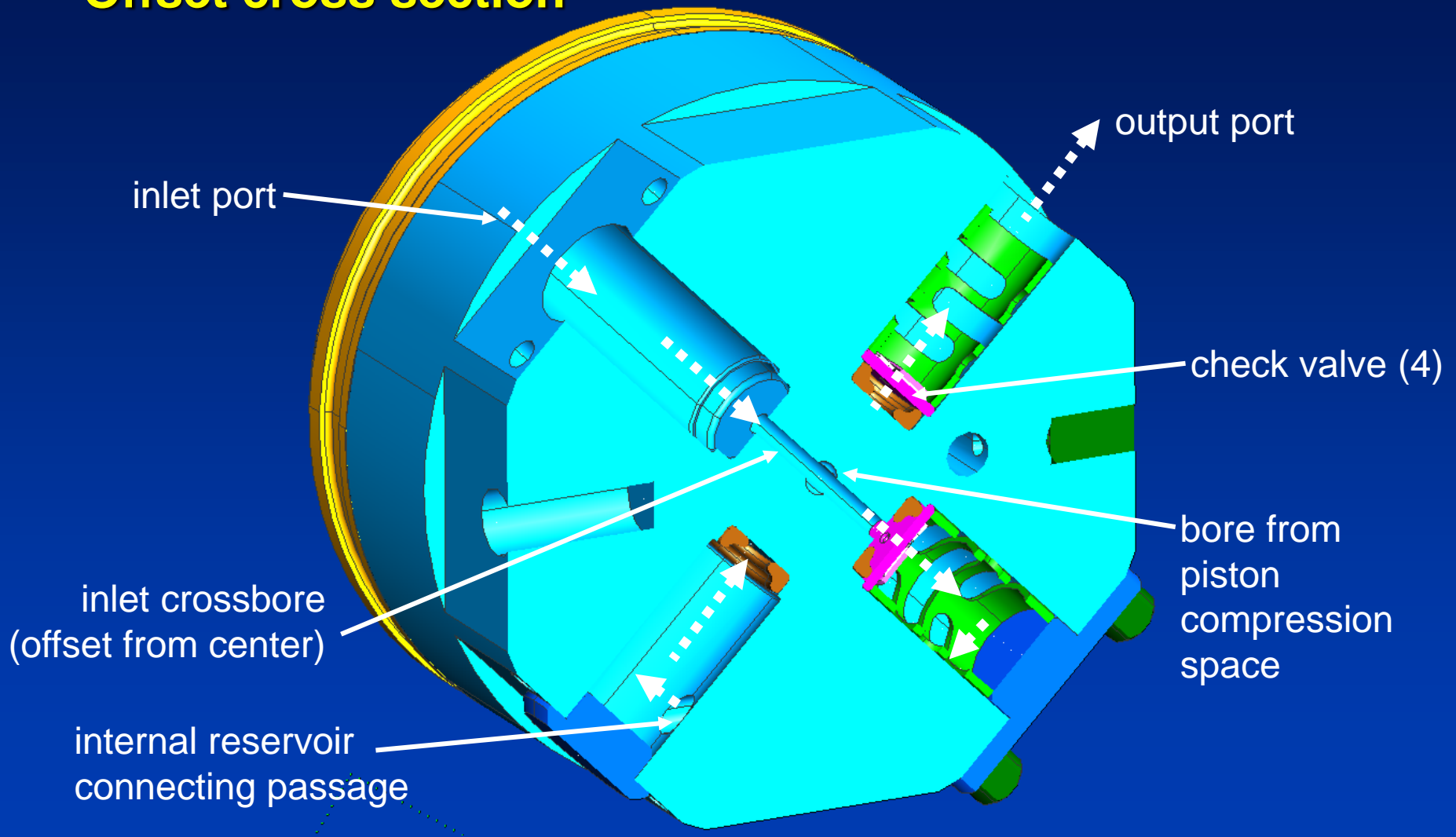
4-Bore Center Hub

Center section



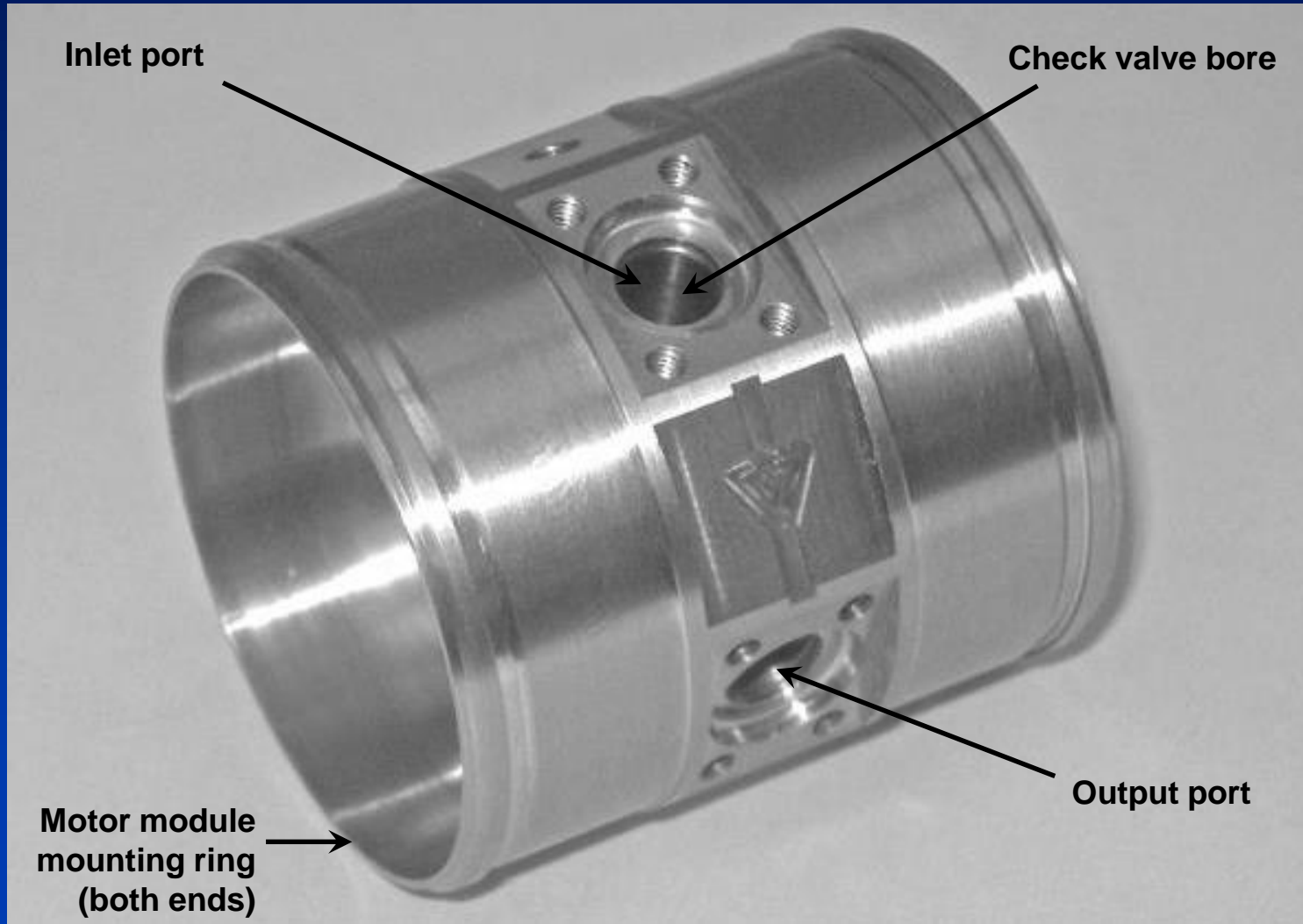
4-Bore Center Hub

Offset cross section



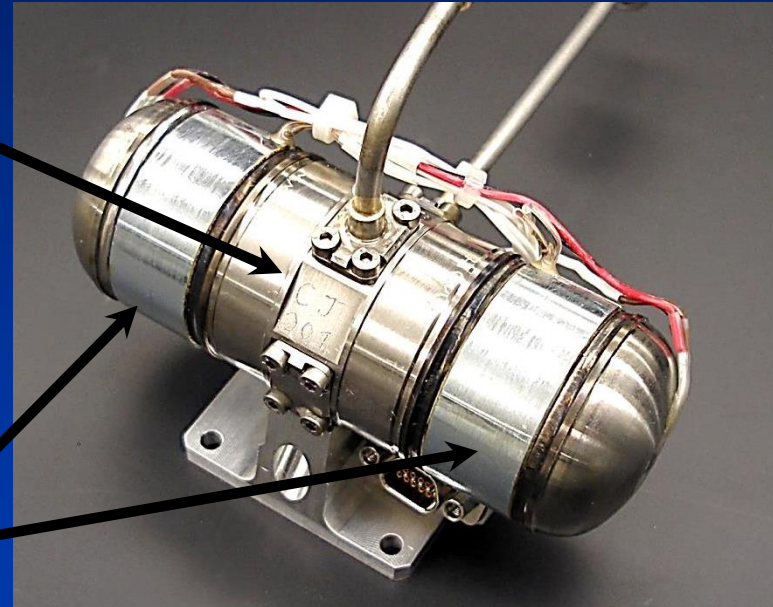
Single Piece Hub

Conventional NC machining



Compressor Assembly

Challenge: Not so difficult



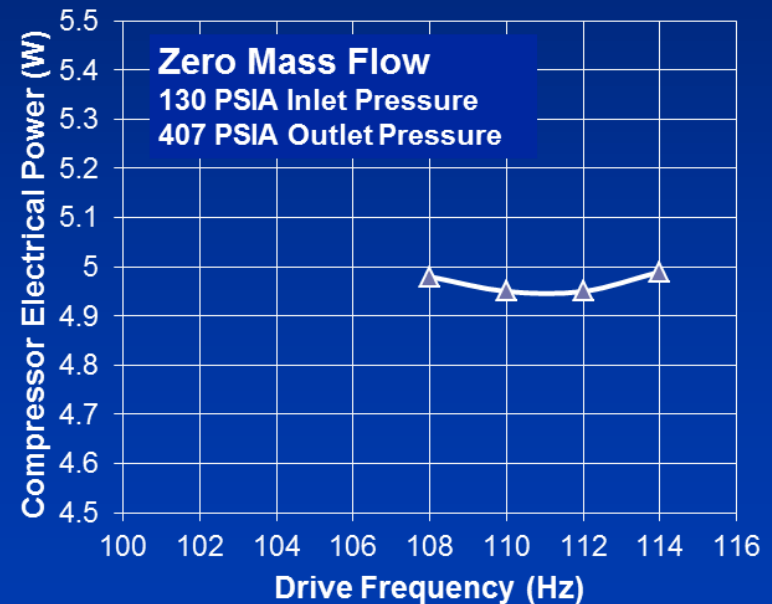
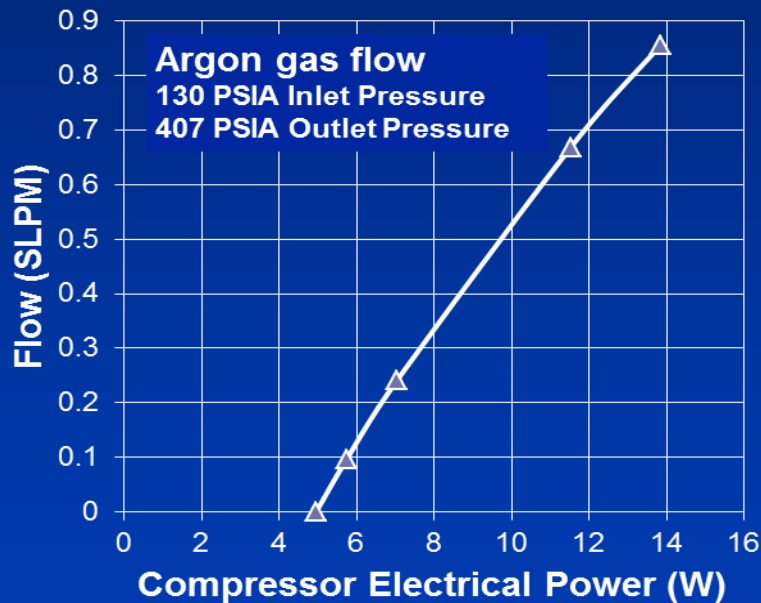
Measured Compressor Flow Rate

Compressor tested using instrumented DC flow loop

Argon gas used as representative of J-T systems

Characteristic flow output with increasing input power

Pressure ratio = 3.1:1



Summary



- ***A Joule-Thomson Micro Compressor was successfully designed, built, and tested***
 - Size and weight are the same as our existing Pulse Tube Micro Compressor
 - Space-quality long life and reliability
 - Utilizes standard low-cost motor modules
 - Capable of delivering steady DC flow at 3 to 1 pressure ratio
 - Designed for operation at cryogenic temperature
- ***Possible applications:***
 - Drive a J-T cold head in a closed loop cryocooler system
 - Fluid pump for remote cooling loop (ambient or cryogenic)
 - Gas circulation applications
 - Other: ***insert your idea here***

Development Project Support



Lockheed Martin Internal R&D Joint Effort



LM Missiles & Fire Control
Santa Barbara Focalplane

and



LM Space Systems Company
Advanced Technology Center