LIGA R&D and Prototyping

D. R. Boehme, J. M. Hruby, W. D. Bonivert, M. A. Bankert,
J. T. Hachman, A. M. Morales, D. M. Skala, S. K. Griffiths,
A. Ting, T. E. Bennett, J. S. Krafcik, Jr., S. D. Leith, D. Chinn
Sandia National Laboratories
Livermore, California 94551-0969

D. Plummer, E. Garcia, M. Polosky, M. Decker
Sandia National Laboratories
Albuquerque, New Mexico 87185

SEMICONWEST 1999

San Francisco, California
July 14, 1999

Sandia has a complete capability for prototyping microparts

CAD File

Electronic Ordering

Mask Layout

Mask Fabrication

Substrate Prep

LEXD

X-ray Exposure

Development

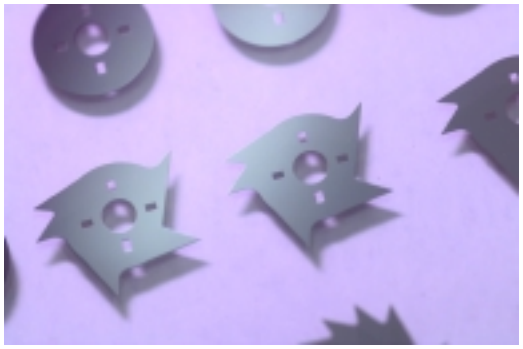
Electroplating

Lapping

Replication

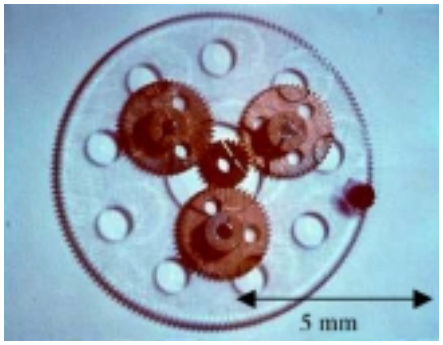
- Dedicated synchrotron lines at SSRL & ALS
- Dedicated personnel for individual process steps and process modeling activity
- Three in-house laboratories: clean room, chemistry lab, electroplating lab
- 180 wafers processed over the past year

Sandia's processing capability has supported a variety of applications



Individual parts

Assembly Tools



Microsystems

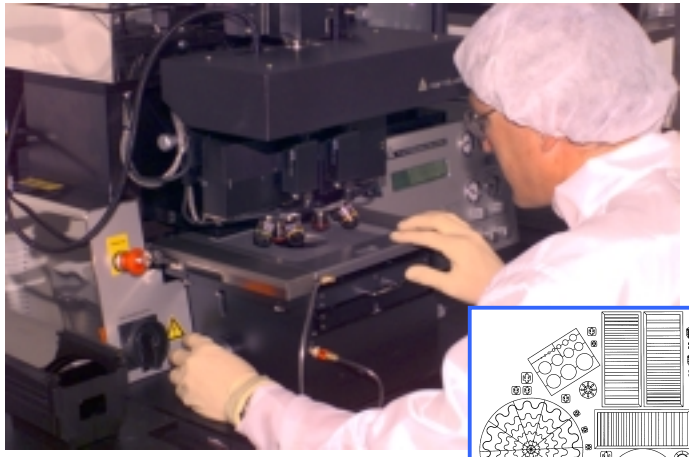
- Defense: low g accelerators, motors, locking mechanisms, precision piece parts
- Instrumentation miniaturization: klystrons, mass spectrometers and wave-guides (with JPL), gas chromatography columns, Faraday cups ….
- Precision Devices: heat pipes, plunge EDM tools, fiber alignment and clamps, micropart assembly tools ….

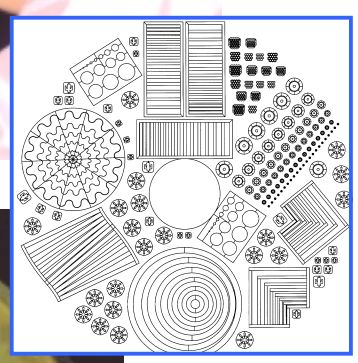
LIGA Processing Capability: Electronic Ordering and Data Tracking

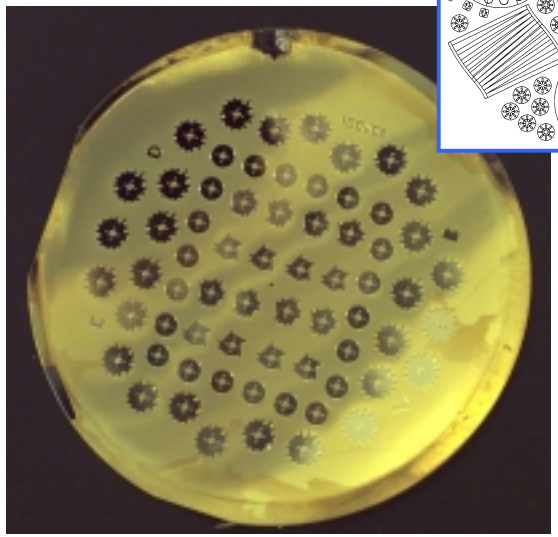
- CAD files and orders can be transferred electronically to an ftp site
- Allows a requester to follow a part through the fabrication process
- Allows members of the fab team to follow parts and processes
- Serves as an inventory record
- Automatically archives process conditions - important for high consequence reliability applications
- Provides the opportunity to search based on process conditions

★ **http://daytona.ca.sandia.gov/LIGA**

LIGA Processing Capability: Masks & Substrate







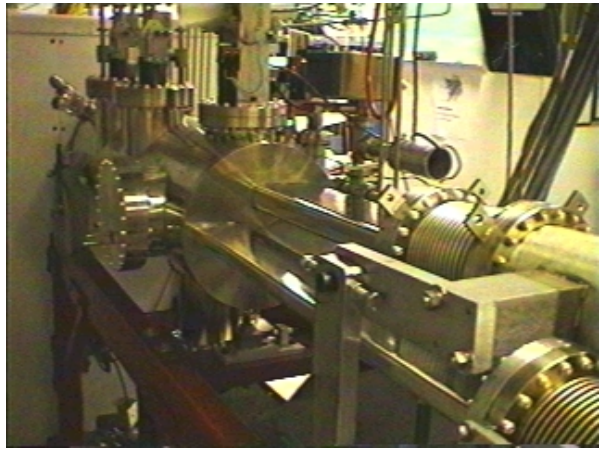
★ LIGA Mask

- Multi-user clean room facilities with class 100 room equipped for lithography
- Silicon wafer 100 microns thick
- 3 or 4 inch diameter format
- Patterned gold up to 30 microns thick using SJR 5740 photoresist, Karl Suss MA6 aligner

★ LIGA Substrate

- CQ grade PMMA used as thick resist
- Bonded to Ti-Cu-Ti metallized 600 micron silicon wafer plating base
- Fly-cut to +50 microns over desired final part thickness

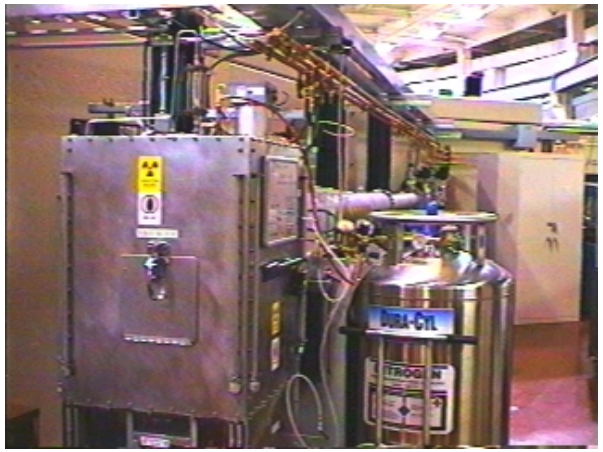
LIGA Processing Capability: Beam Lines



★ **SSRL - Stanford Synchrotron Radiation Laboratory**

- SSRL BL2-2 has been used by the West Coast LIGA Group (Sandia, JPL, LBL) since 1995 using an independent experimenter proposal
- SSRL BL3-1 is a dedicated LIGA station to be operated by Sandia and JPL and scheduled for commissioning in July 1999

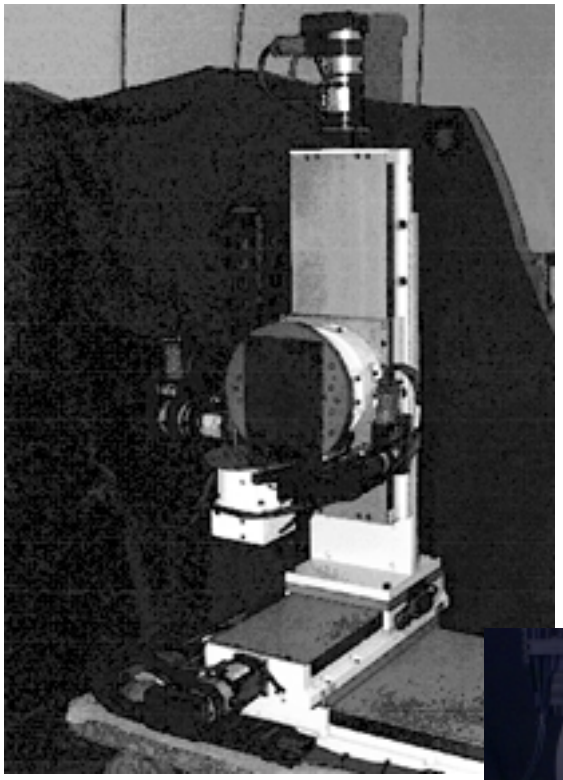
LIGA Processing Capability: Beam Lines

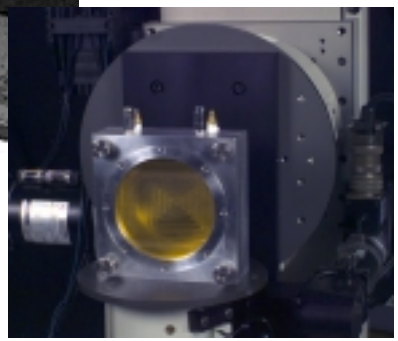


★ **ALS - Advanced Light Source**

- ALS BL3.3.2 is shared by the West Coast LIGA Group (Sandia, JPL, LBL) and consists of a self-contained end station dedicated to LIGA
- The X-ray exposure scanner consists of a turret design capable of mounting multiple masks simultaneously

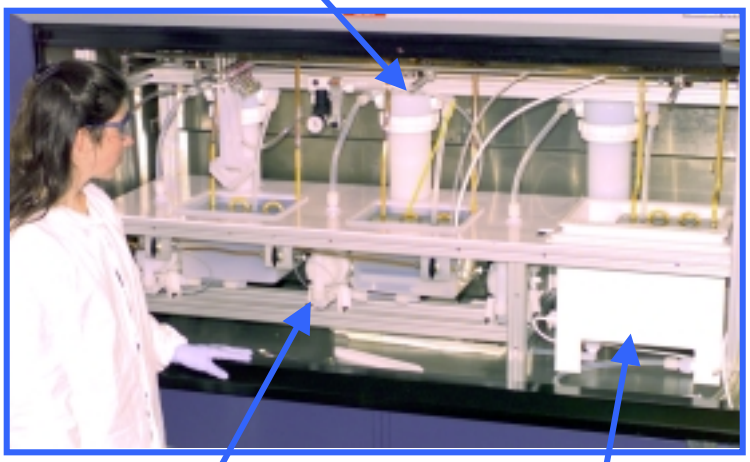
LIGA Processing Capability: X-ray Scanner





- ★**SSRL BL3-1 will incorporate a 5 stage instrument for exposing samples using Deep Etch X-ray lithography:**
  - Vertical Z-axis scanning stage with 18 inches of travel
  - Horizontal X-axis with 12 inches of travel
  - Horizontal Y-axis with 24 inches of travel
  - Two rotational stages to which the mask holder is attached
  - Labview control and data acquisition
  - Laser and camera sample alignment

LIGA Processing Capability: Development



★ **Megasonic development system:**

- Three tanks:
  - GG developer
  - intermediate rinse
  - water rinse
- 0.2 micron teflon filtration
- This system can handle multiple 3” and 4” substrates; megasonics is incorporated into the developer and intermediate rinse tanks
- A camera and video system mounted to the hood is used to monitor the development progress

LIGA Processing Capability: Electroplating & Planarization

★ Electroplating

- 16 tank plating line for copper, nickel, permalloy, gold, research
- 5 micron bath filtration
- computer-based diagnostic and control - specialty waveform generation

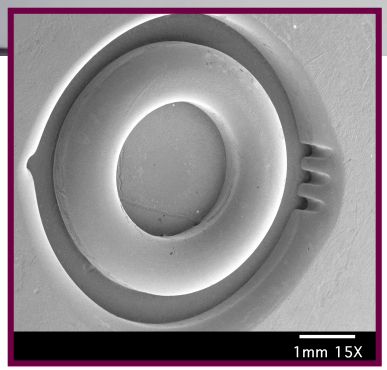
★ Planarization

- Engis lapping equipment & diamond slurries
- modified vacuum fixture to hold wafers
- thickness tolerance is+/- 5 microns with surface finish of 1 micron rms

LIGA Processing Capability: LEXD computer code

- ★ Provides integrated calculation of both exposure and development and supports all synchrotron sources in use by Sandia
- ★ Filter set and mask design is greatly simplified and can input:
  - filter and mask elements directly -- code computes dose
  - top or bottom dose -- code computes exposure time
  - top and bottom dose -- code selects filters and time
  - masked dose or side wall erosion depth -- code selects mask thickness and filters and time
- ★ Development rates and total time are computed for both masked and exposed regions:
  - calculations include dissolution kinetics and fragment transport
  - results provide estimate of development time as well as side wall erosion and potential for undercutting of substrate

LIGA Processing Capability: Replication



Standard Lucite
PMMA sheet

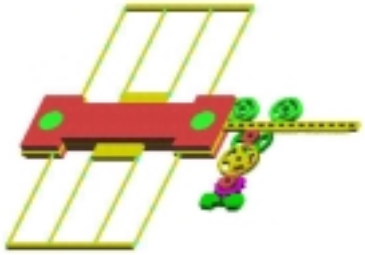
★ Polymeric replication

- Hot embossing:
  - replication quality vs material using modified Instron machine
  - mold technology
  - high flow / low flow parameters
- Injection Molding:
  - Acquisition of vertical molding machine

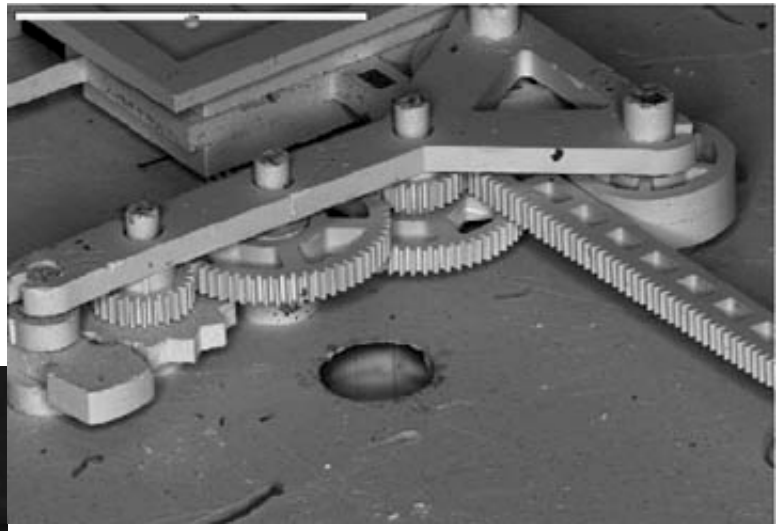
★ Ceramic replication

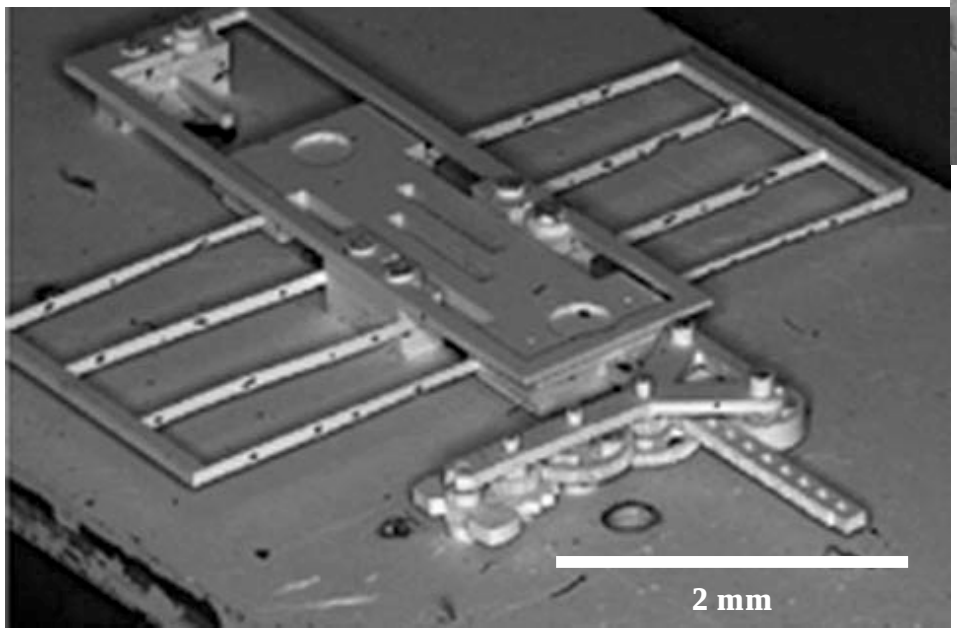
- nanoparticles + polymeric binder + LIGA mold

LIGA Accomplishments



Microtrajectory safety subsystem component to provide enhanced safety for weapon systems





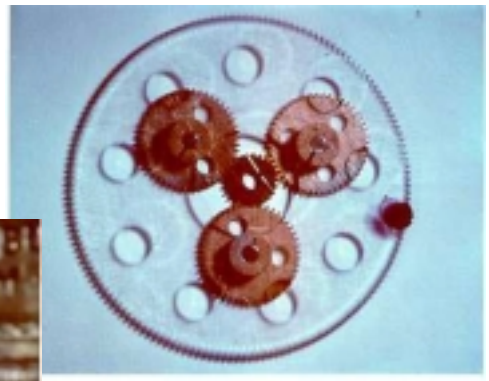
Environmental Sensing Device

- 10mm x 6mm x 3mm package
- 45 piece parts
- 25 - 500 micron thickness
- copper, nickel, nickel/iron

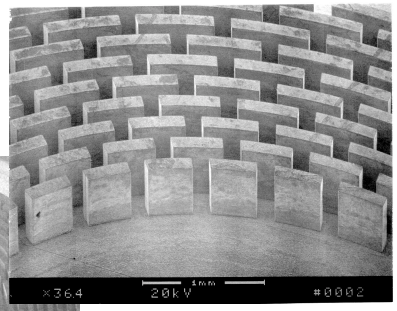
LIGA Accomplishments

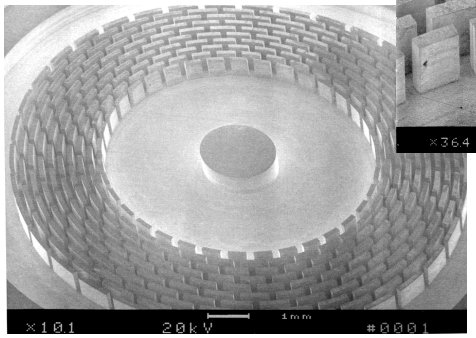
Millimotor:

- Variable reluctance
- 8 mm dia x 3 mm deep



- 30 LIGA parts
- 4 materials (PMMA, copper, nickel, permalloy)
- 3 week delivery



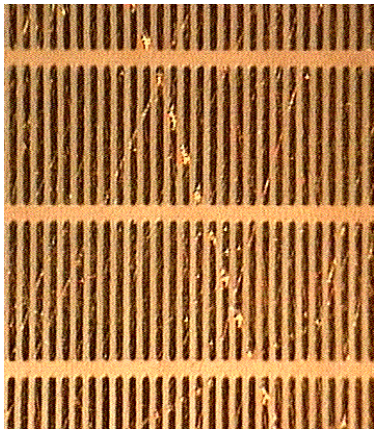


EDM Tool:

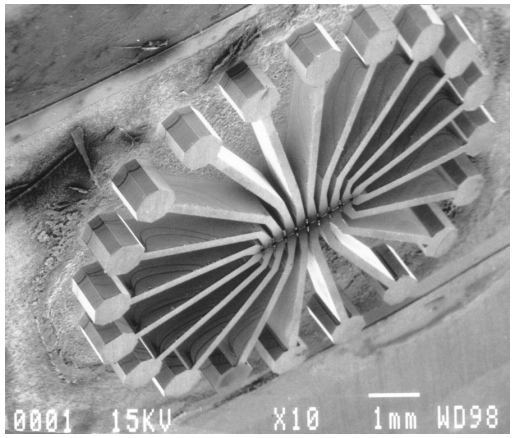
- kovar and stainless steel parts
- 1 mm thick, 15 mm dia

- 6 patterns on each wafer
- copper patterns on copper substrate
- Current R&D for polymeric replication to reduce cost

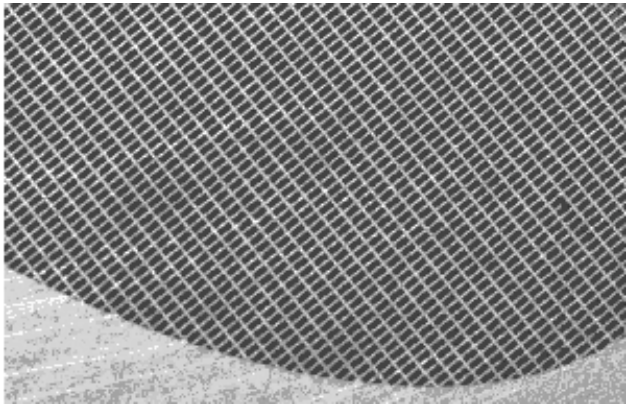
LIGA Accomplishments



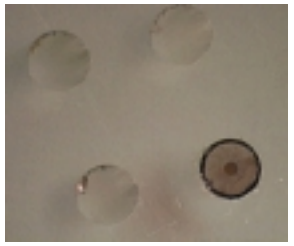
X-ray imaging grid
(JPL/SNL)
34 micron pitch



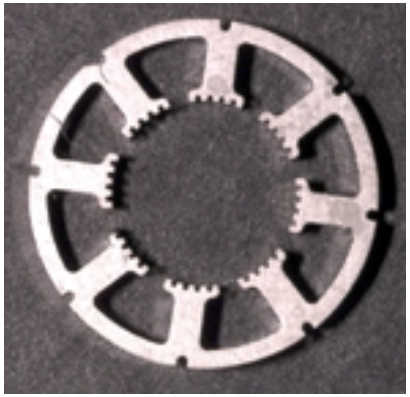
Mass spectrometer
component 1 mm thick

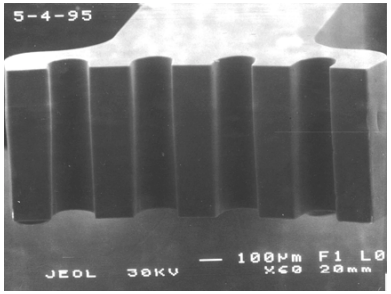


640 GHz wave-guide
(JPL design /SNL plated)
40 micron wide slats;
320 x 144 micron openings



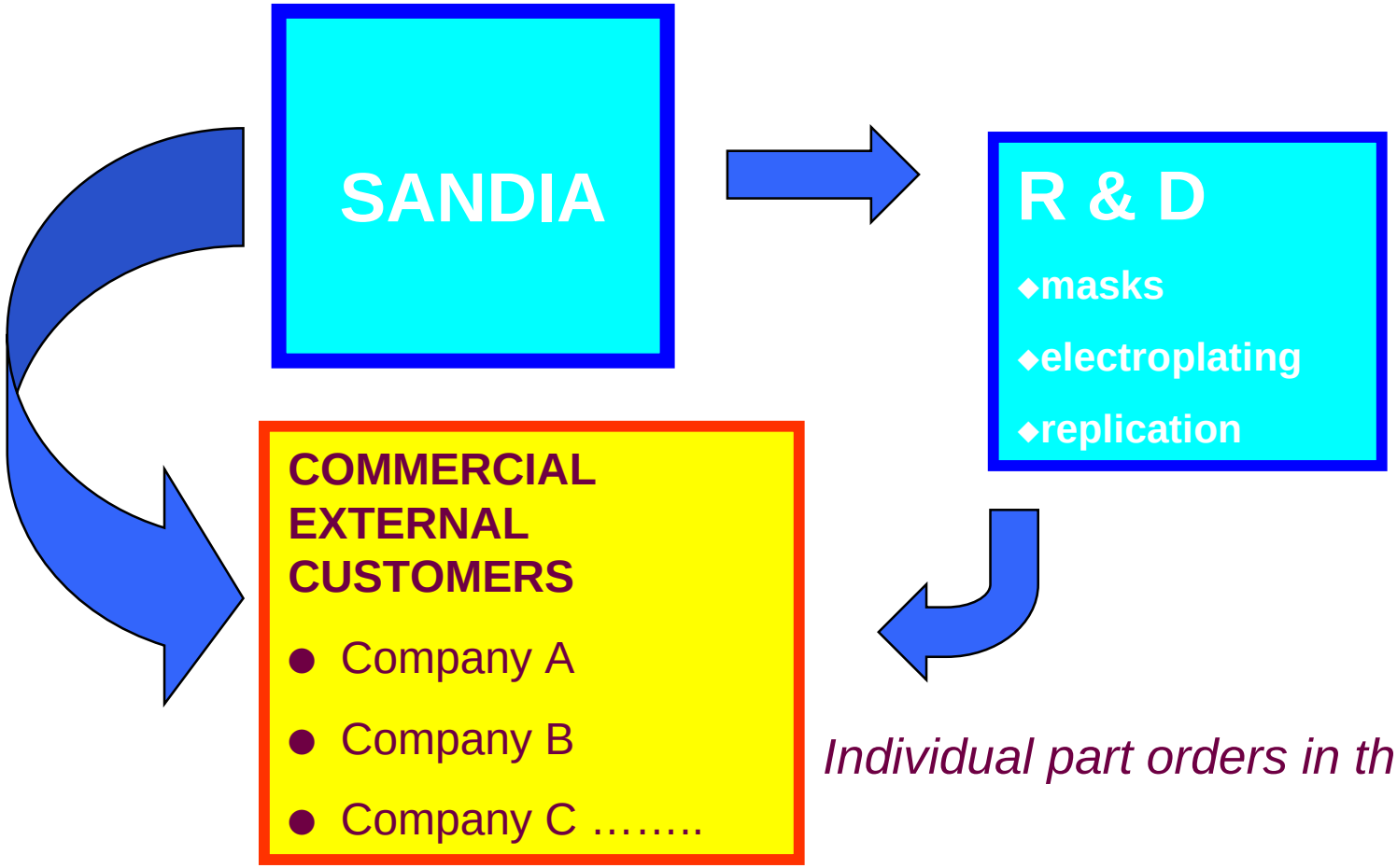
Micro Electro-chromatography capillary connectors
(SNL)





Precision stepper motor
(LBNL/SNL)
Step Size 1.8 Degree, Ni/Fe Alloy
Requires vertical side wall and high precision

What's Today?



Individual part orders in the 100's

What's Tomorrow?

What's Tomorrow and The Next Day?

- ★ **If external LIGA business increases !**
  - more machines ?
  - more people ?
    - more continuous $?
- ★ **Sandia would provide the interface and R&D when needed**
  - 1 FOUNDRY
  - more than 1 FOUNDRY?

EXTERNAL LIGA

Individual part orders
in the 1000's - 10,000'S