# Industrial Studies of ILC Cavities & Component Production in the Americas

## IPAC 11 – Kyoto, Japan

## May 23, 2010


Science Projects
Homeland Security
Medical Imaging
Defense


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Putting Accelerator Technology to Work

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- AES Production Philosophy
- 1st US Industrial Cost Study for the ILC
- Fermilab and SBIR Contracts to Study Cost Reductions for Cavity and He Vessel Manufacturing
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# WHAT IS THE ILC?

**GDE DIRECTOR**
**BARRY BARISH, HAS STATED THAT**
**"THE ILC IS A PROJECT NOT A LABORATORY"**

**THE SPAFOA BELIEVES THAT THE ILC IS A PROJECT NOT A BUSINESS**

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# PRESENT STATE OF US MANUFACTURING

- US industry has **almost no experience** with assembly and integration of large cryomodules for SRF Cavities
- US industry has the capacity to tool up for the manufacturing of most of the ILC components with the exception of the SRF cavities. SRF cavity manufacturing is still in the infantile stage
  - Machining niobium
  - E-beam welding of niobium
  - Chemical processing

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# INDUSTRIAL INVESTMENT?

- For industry to make investments in infrastructure the size required for the ILC there would need to be a large follow on market
- What follow on market? The ILC is a project not an ongoing business. Post ILC there will be no need to maintain this capacity
- There not be a resulting demand to support the continuation of the ILC manufacturing infrastructure

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# APPROACH

- A government-owned facility ("The Factory") will provide the equipment and space for SRF cavity fabrication and processing, plus integration and checkout of the cryomodules
  - Industry will staff The Factory, under Government contract
- RF Equipment will be procured through the local ILC program infrastructure – not through The Factory

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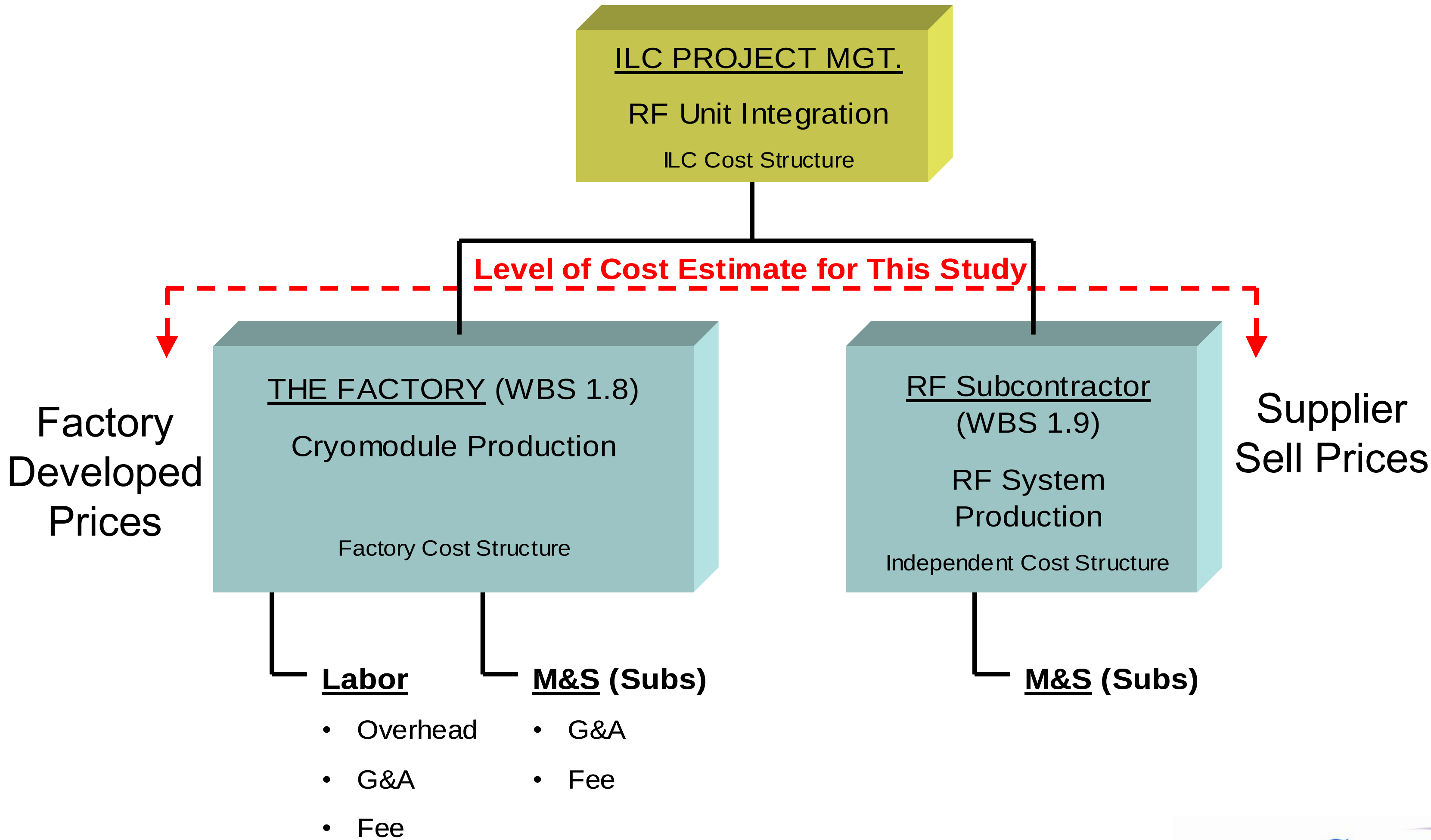
# COST MODEL




Reference: Sredniawski, Bonnema, "ILC RF Unit Industrial Cost Study Methodology & Results" (2007)

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# ILC RF Unit Industrial Cost Study
# Methodology & Results

Funded by FNAL

CY2006/2007)

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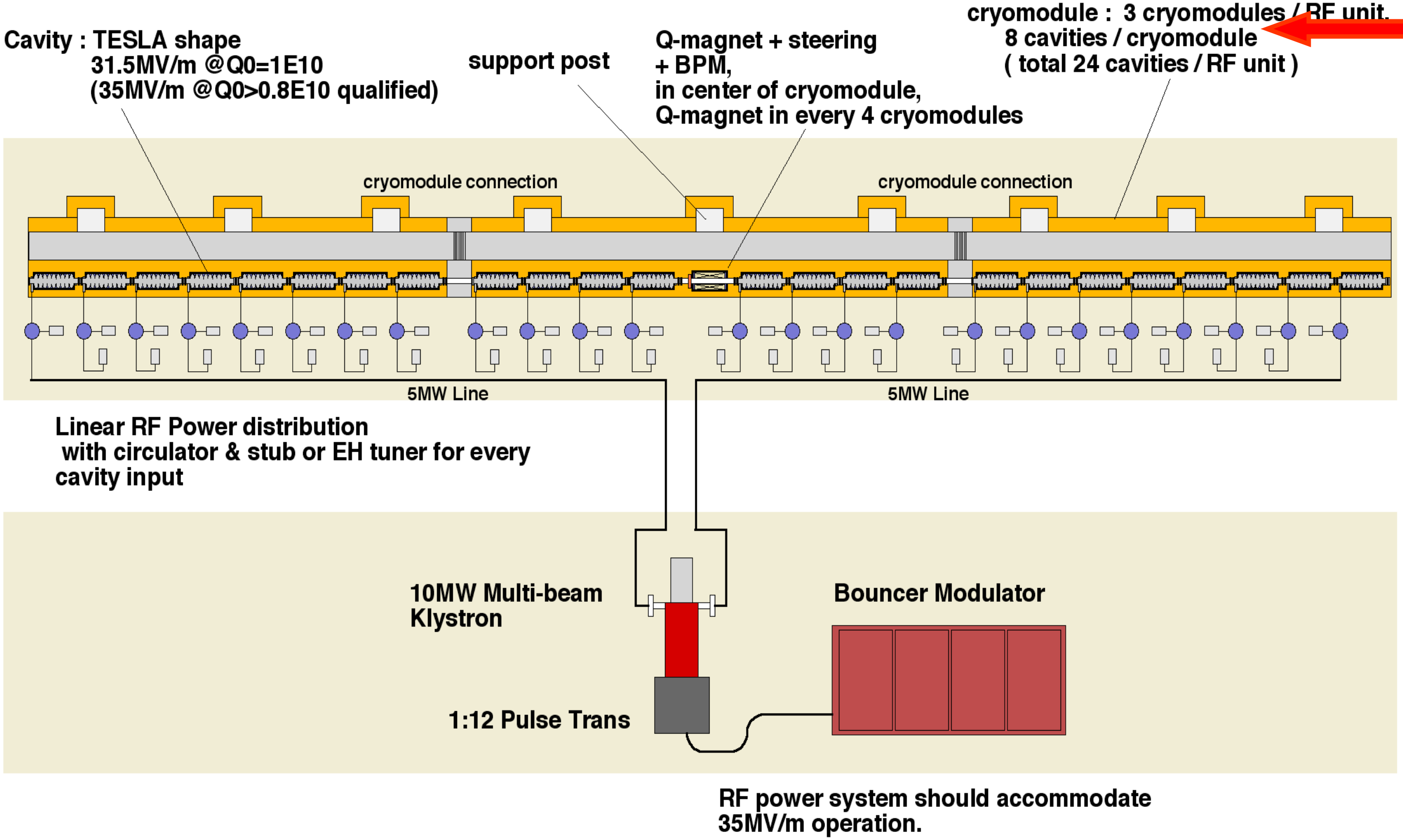
CPI Communications & Power Industries beverly microwave division

MEYER

# RF Unit Configuration

## (8 Cavities/Cryomodule)




Note: The RF Unit configuration has since been changed from 24 to 26 cavities

An RF Unit consists of 3 cryomodules and one RF power system

# Planned Production Rate

| Year | RF Units Annual Production Rate |
|---|---|
| 1 | -- |
| 2 | SOP @ 20 months |
| 3 | 6 |
| 4 | 36 |
| 5 | 82 |
| 6 | 86 |
| 7 | 40 (only ½ year) |

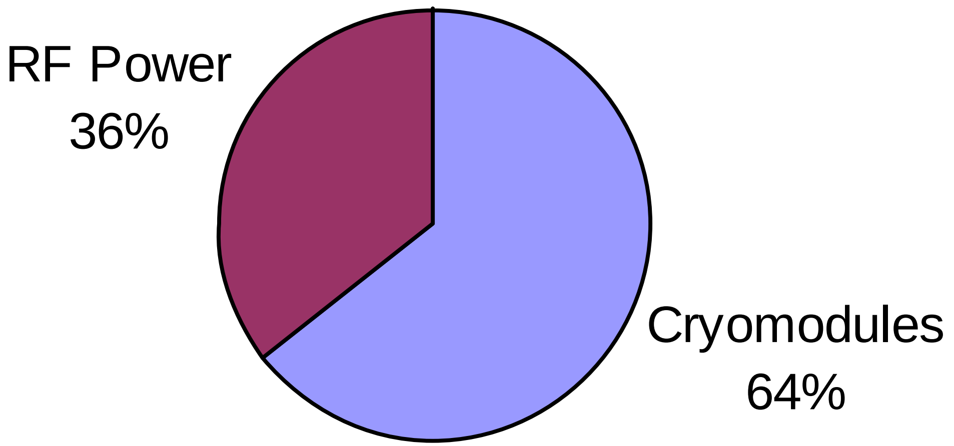
Production work in The Factory begins after 20 months to allow for factory setup and startup.

Procurement of materials and RF subcontracts can begin during the first year.

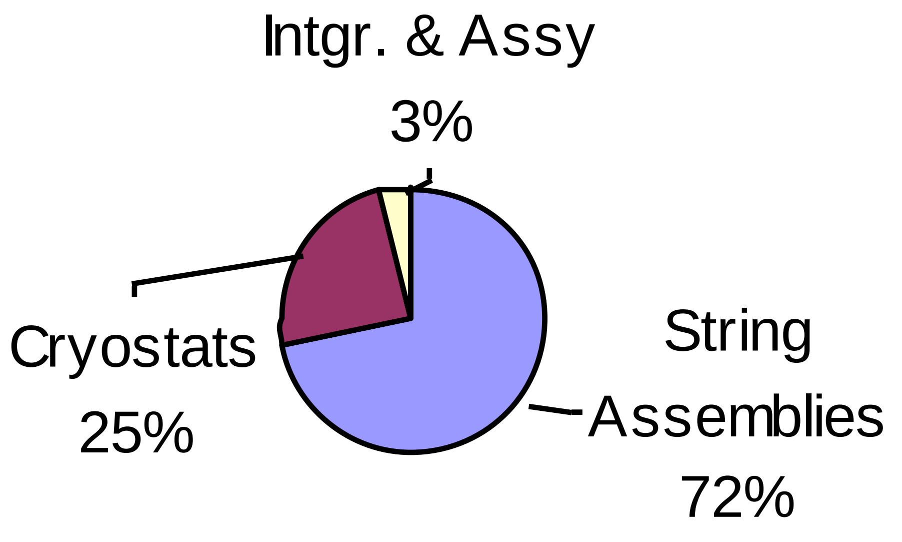
Peak rate of 9 SC cavities per day

# Cost Drivers

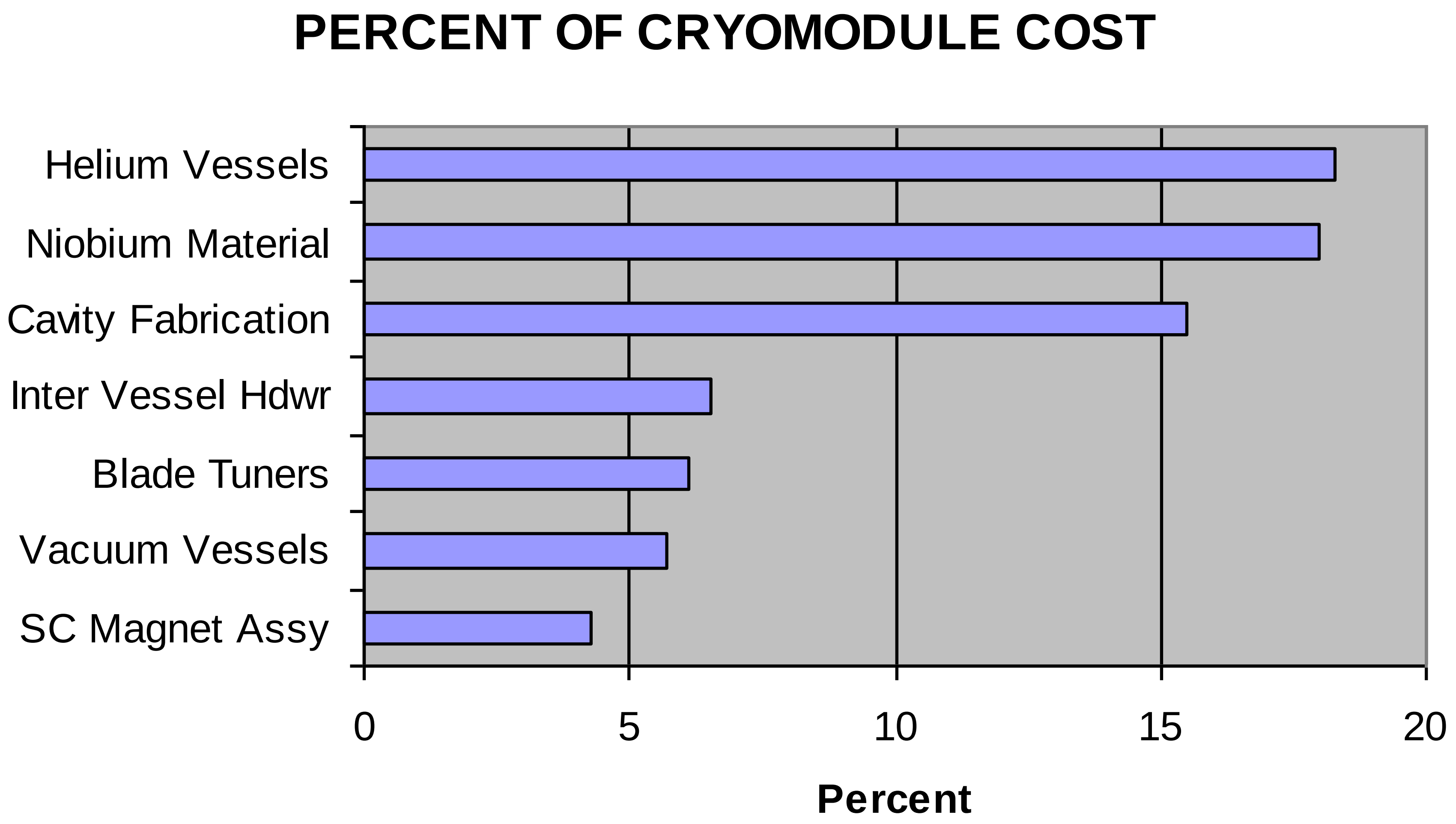
**RF UNIT COST**




**CRYOMODULE COST**



# Cost Drivers



# Factory Equipment Requirements

For the Nominal Production Run of 250 RF Units

| Equipment Description | Quantity |
|---|---|
| Niobium Material Scanners | 6 |
| NC Machines | 11 |
| BCP Systems | 2 |
| E-Beam Welders | 18 |
| RF Tuning Benches | 8 |
| Electro-polishing Systems | 7 |
| High Temp. Vacuum Ovens | 7 |
| High Pressure Water Rinse Systems | 12 |
| VTA Systems (may be able to share RF power) | 18 |
| String Assembly Lines | 5 |
| Vacuum Vessel Final Assembly Fixtures | 5 |
| Cryomodule Integration & Assembly Lines | 21 |

# Summary & Conclusions from 1st Study

- This was the first time that US industry had participated in ILC costing
  - Presented costs were realistic based upon available knowledge
- Some WBS element costs may be reduced further by:
  - Design configuration refinements
  - Cavity processing optimization
  - Manufacturing optimization & workflow improvement
- The few key companies that have been previously involved in SC cryomodule fabrication were responsive to our cost inquiries
- There was very little demonstrated interest by other outside fabricators to participate
  - They did not believe it is real
  - It will interfere with their present long term business

# Follow-up Recommendations

- Evaluate potential revisions to the present cost study
  - Incorporate the latest guidance of the GDE on configuration & processing
- Develop qualified set of contract machining companies for niobium cavity parts
  - Potentially significant (~25% ) cavity fabrication cost reduction
- Develop process improvements (fabrication & processing)
  - Study was based mostly upon present methods
- Develop cost estimate for design & fabrication of special production tooling for cryomodule fabrication & assembly
  - This was not part of the initial study scope
- Develop plan & cost estimate for “The Factory” setup
  - This was not part of the initial study scope (significant project cost)

# ILC Cavity Fabrication Optimization for High Quantity Production

- **AES was awarded a contract by Fermilab (PO # 577516) in December 2007**

# Cavity Fabrication Optimization Study Flow Chart

Cost Elements of Fabrication → Fabrication Optimization → Develop 1st Production Article Data

↓

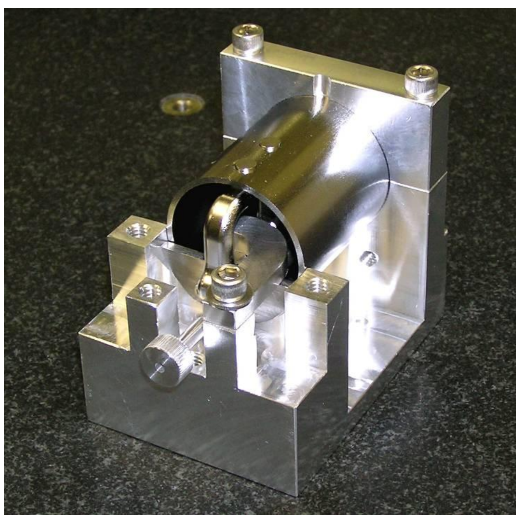
Develop Spreadsheet

↓

Cost per Cavity

↓

Cost Distribution



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# Cost Elements of Fabrication

**Touch Labor (Subject to Learning Factor)**

*Parts Handling, Manual Fabrication Operations*

**Touch Labor (Governed by Process Time)**

*Machining, Welding, Parts Indexing & Positioning*

*Modifiable by Multiple Machine Ops. (labor factor)*

**Unattended Operation (Lowest Cost)**

*Spindle Time, Fully Automated Operations*

**Non-recurring Labor**

*Setup & Breakdown, CNC Programming*

**Expendables & Maintenance**

*Tool Bits, BCP, Machine Cleaning*

# Fabrication Optimization

**Optimize Staffing**

*Maximizes Learning Effect*

**Batch Processing**

*Minimizes Piece Part Cycle Time*

**Optimize Raw Material Shapes**

*Minimizes Machining Time*

**Use Alternate Machining Methods**

*Reduces Attended Labor*

**Maximize Unattended Operations**

*Lowest Cost*

# Development of 1st Production Article Data

**Based on Fabrication of ILC Prototype Cavities**

*Real Experience*

**Shop Work Orders Defined Steps & Initial Values**

*Measured Touch Labor Times, Actual CNC Operations Times, Actual Welding Times, Actual Parts Handling & Indexing Times*

**Considered Alternate Machining Approaches**

*Milling vs. Turning, Raw Stock Forms to Reduce Machining*

- Three (3) sizes of welders were identified:
  - *30 wide X 30 high x 24 deep*
  - *36 wide X 36 high X 50 deep*
  - *60 wide X 24 high X 120 deep*

# Welder Systems Trade Study

## SUMMARY

**Single chamber welders are most cost effective for use on the ILC program**

Touch labor cost is a wash (less than 2% difference with single chamber being less)

Lower capital costs.  For production of 6000 cavities:

*$10.6M (16 welders) for single chamber*

*$12.6M (11 welders) for dual chamber*

Lower operating cost:

*Roughly 27% due to lower number of vacuum pumping systems*

Further consideration must be given to the following:

*Dual chamber welders are less reliable*

*Failure of a dual chamber machine results in a larger reduction in production capacity*

# Developed Spreadsheet to Include:

**Required Production Rates**
**All Cost Elements for Each Operation**
**Fabrication Optimization**
**Worker Productivity Factor @ 90%**
**Production Yield @ 95%**
**Effect of Learning @ 90%** (RHIC experience)

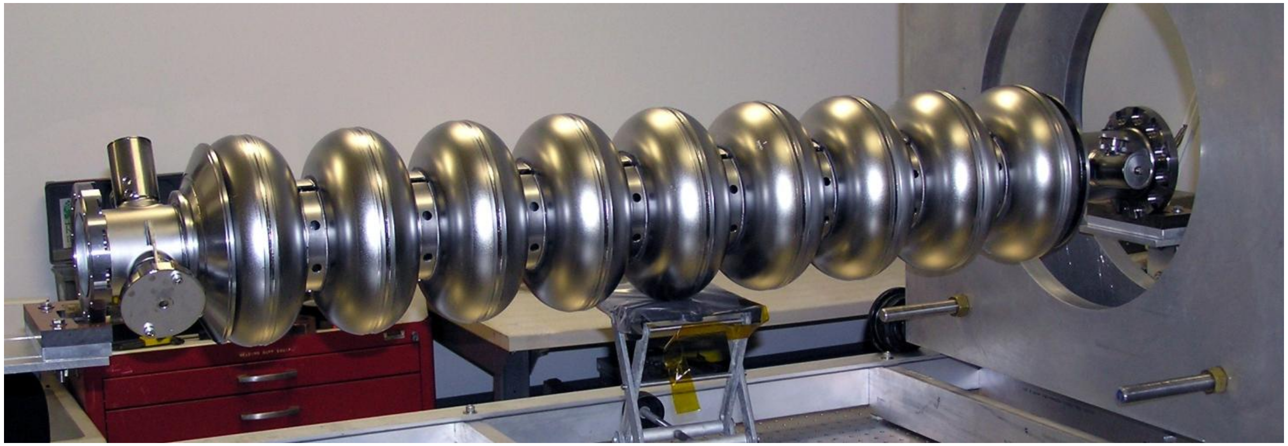
## POSSIBLE COST PER CAVITY (less material)

| Categories | Hours | | Assumed Rates | Cost |
|---|---|---|---|---|
| Touch Labor | 88 | | $80 | $7,040 |
| Unattended | 30 | | $40 | $1,200 |
| Support Labor | 35 | @40% of touch | $100 | $3,500 |
| Mgt. Labor | 11 | @12% of touch | $170 | $1,870 |
| Expendables & Maintenance | | | | $425 |
| TOTAL | 164 | | | $14,035* |

*Average unit cost for 6000 unit production excluding subcontracting costs & shipping

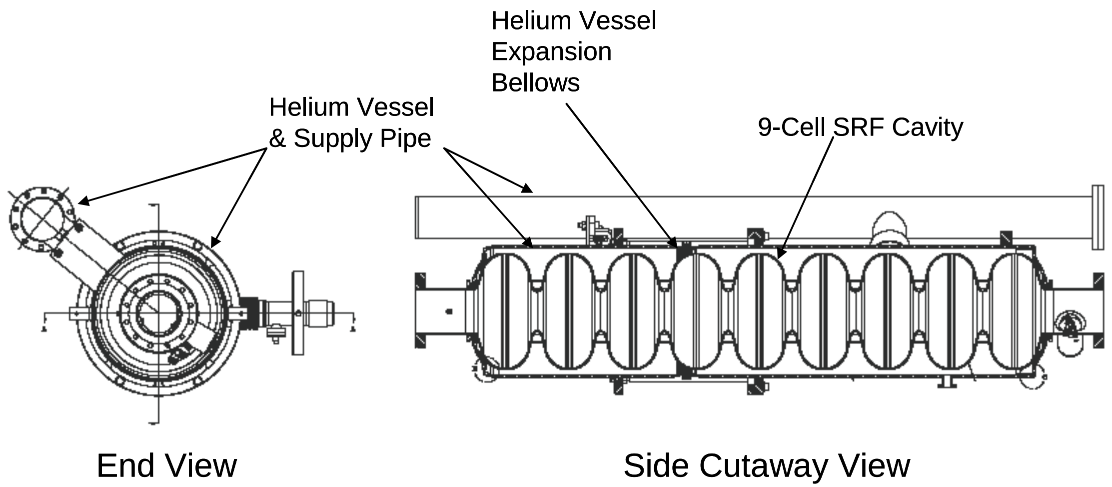
# COST DISTRIBUTION

| Cost Category | Percent |
|---|---|
| Machining | 59 |
| BCP | 8 |
| Welding | 21 |
| Tuning | 5 |
| Special Inspection | 1 |
| Hydroforming | 3 |
| Expendables & Maintenance | 3 |



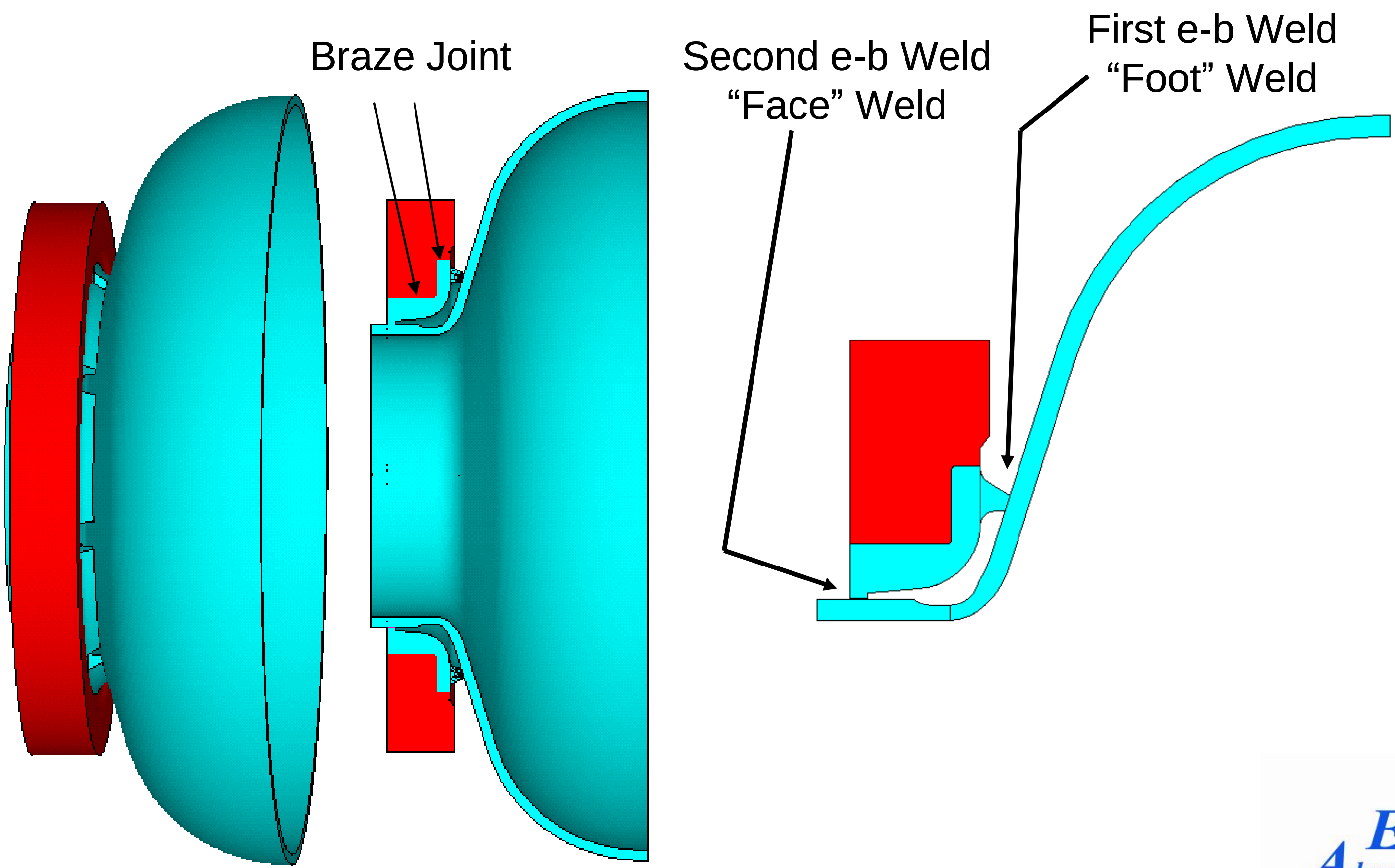
# ILC He Vessel Design for Cost Reduction

- AES was awarded a Phase I Small Business Innovative Research (SBIR) contract in 2008 by the DoE to investigate the redesign of the ILC He vessel to reduce its cost
- AES was awarded a Phase II SBIR in 2009 to modify the ILC cavity and He vessel design and fabricate a dressed ILC cavity with a stainless steel He vessel



# End Cap Niobium to SS Braze is Key

Need to optimize thermal movements/loads

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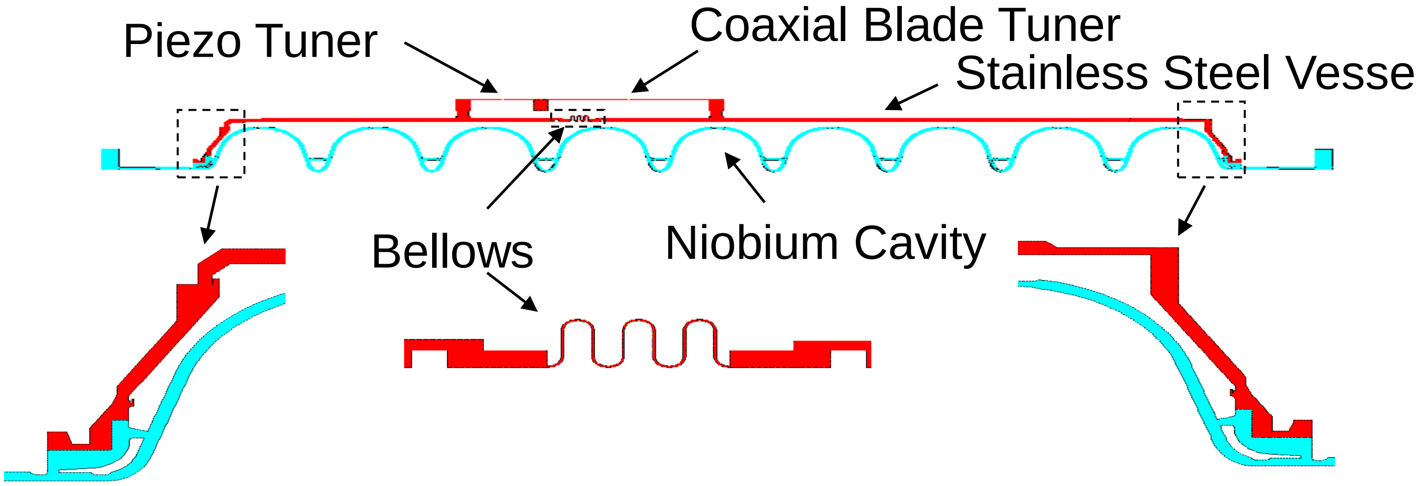
# ANSYS Model

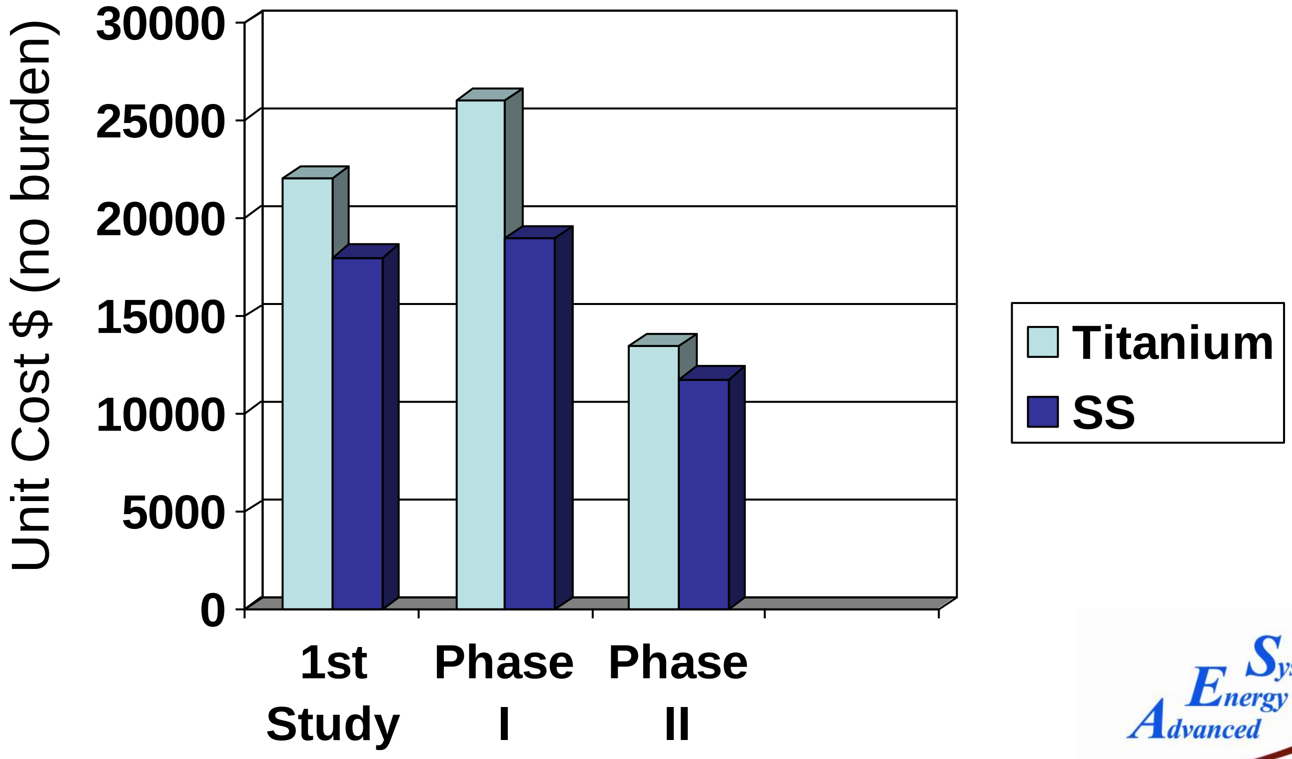



- Must keep blade tuner loads below 12kN for <u>ALL</u> operational and failure modes
  - Requires bellows re-design
  - Pre-stretch of cavity required during final assembly
- Use of SS tuner with Inconel 718 blades

# Helium Vessel Cost Trend

Based upon a production run of 6000 units (incl. NRE)

During the 1st study we only had a conceptual design. During the Phase-I SBIR realistic designs were evaluated. Phase-II costs were obtained after production optimization. Results from the Phase-II SS prototype will result in the most realistic production costs



# Summary

- The ILC is a project and not a business for the production of the SRF cavities and the cryomodules.
- US industry conducted a cost study for ILC RF Units and identified the cost drivers. The study was based on utilizing a government facility with government purchased infrastructure but operated by US Industry.
- AES has done a very detailed study on two of the identified cost drivers namely: cavity production optimization and a redesigned He vessel. These studies indicate a possible cost savings of over $340M from the cost in the 1st US Industrial Study
- Factory optimization and setup along with the logistics of skilled staff planning is still required