

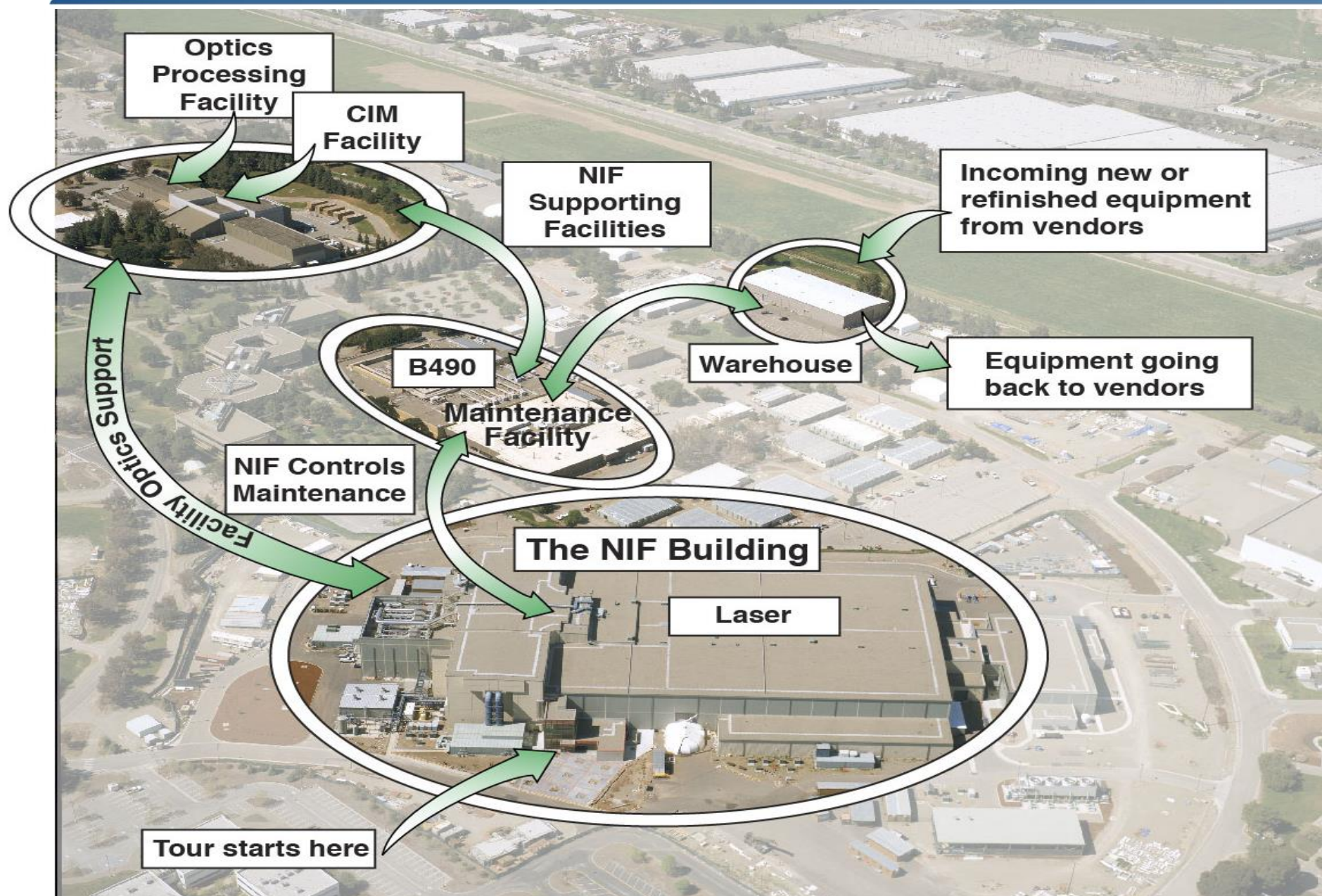


Designing and Implementing LabVIEW Solutions for Re-Use

**Presentation to
14th International Conference on Accelerator & Large
Experimental Physics Control Systems (ICALEPCS)
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To operate the NIF requires support from many auxiliary support facilities.



The Optics Mitigation Facility, completed in 2010, helps meet NIF's requirement for near perfect optics.

Process Supervisor.vi rev. 1033

Inspect Exit Surface, Pre-mitigation

One site per flaw ID (the primary site) can be mitigated by the automation process. Other sites using this ID (the secondary sites) must be mitigated manually... Center the primary site in the FOV by Control-Click center. Click "Continue" button when done.

Continue Enable Manual Focus

Workpoint: 1 of 1 Defect Name ID:

Fwd uScope Status: Tracking On -- Exit Surface -- HMI

ROI Size (um): No ROI Defined

Crosshair Gap <Adjust> Gap (um) 164

Workpoint Comments:

Motion Control Status (MCE)

	Position (mm)	Limit Status	Home State	Error Status	Z Tracking
Horizontal (X)	203.000	Off Limit	Found	No Error	
Vertical (Y)	393.301	Off Limit	Found	No Error	
Rev. uScope	-5.251	Interlocked	Found	No Error	Disabled
Fwd. uScope	115.341	Off Limit	Found	No Error	Fwd. Surface
CO2 Lens	-59.410	Interlocked	Found	No Error	Disabled
STIL Probe	-61.109	Interlocked	Found	No Error	Disabled
OCT	-63.621	Interlocked	Found	No Error	
FPL	-60.494	Interlocked	Found	No Error	

Clear MCE Errors

Server Status

MCE Connected
LCC Connected
Vision Connected

Chiller Status

Temperature OK
Flow ALARM

Order 0 0.000 W Database Type: PRODUCTION
Order 1 -0.019 W

Operator Comments:

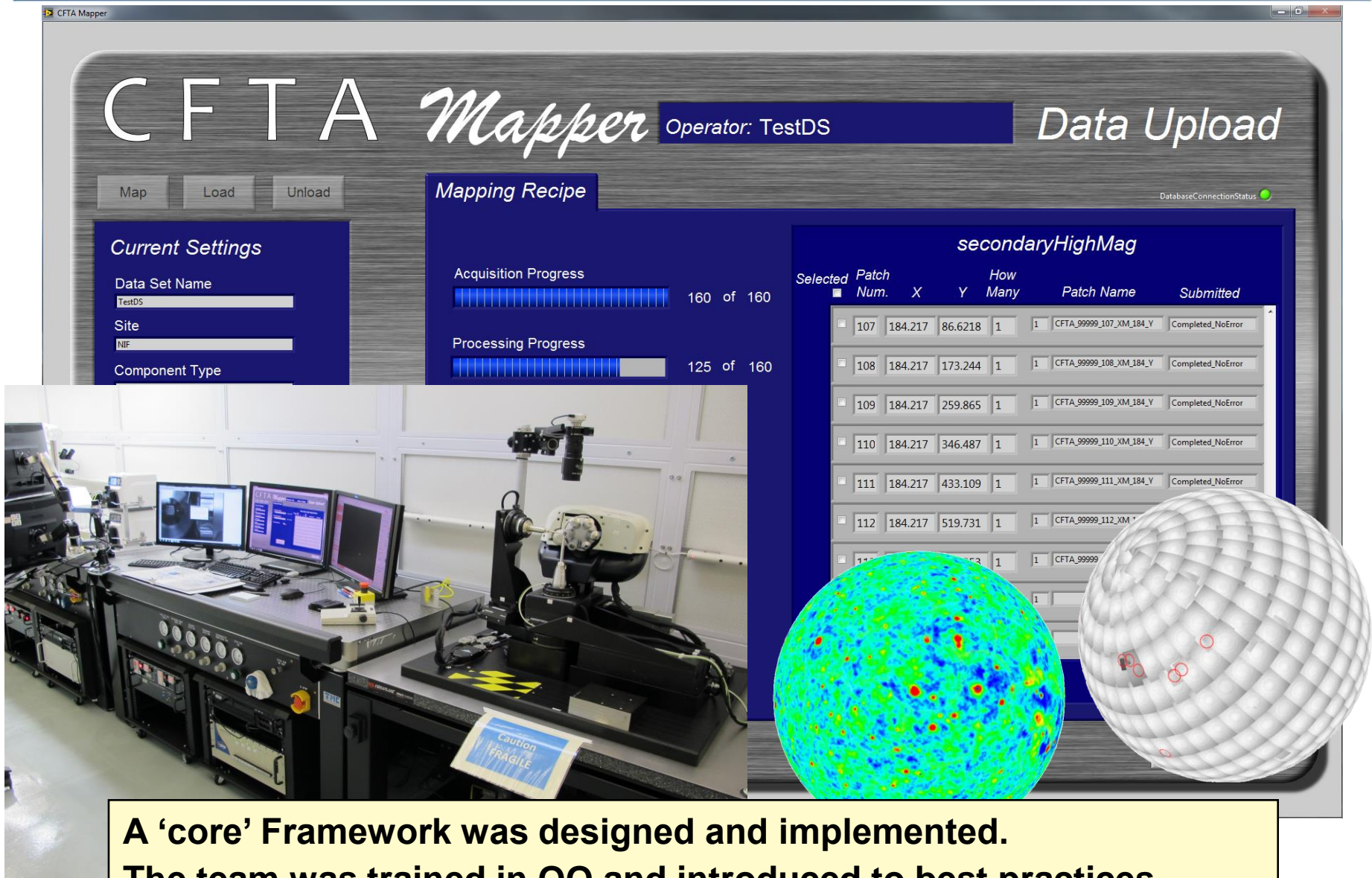
Log Comments

Recent Events:

03:27.0000000000000000 P8004=1.0000000000000000
26:49 Pmax Send Command: P8000=701
00:11.6822135457286 P8003=-0.1733325745121
P8001=-2.0000000000000000 P8004=1.0000000000000000
15:26:62 Pmax Send Command: P8000=701
P8001=-0.01038403453440 P8002=-0.03634412067040
P8003=2.0000000000000000 P8004=1.0000000000000000

From its success, the Lab Systems team was formed to develop controls for machines using Software Engineering best practices.

The CFTA Mapping system characterizes capsule surface features using confocal microscopy.



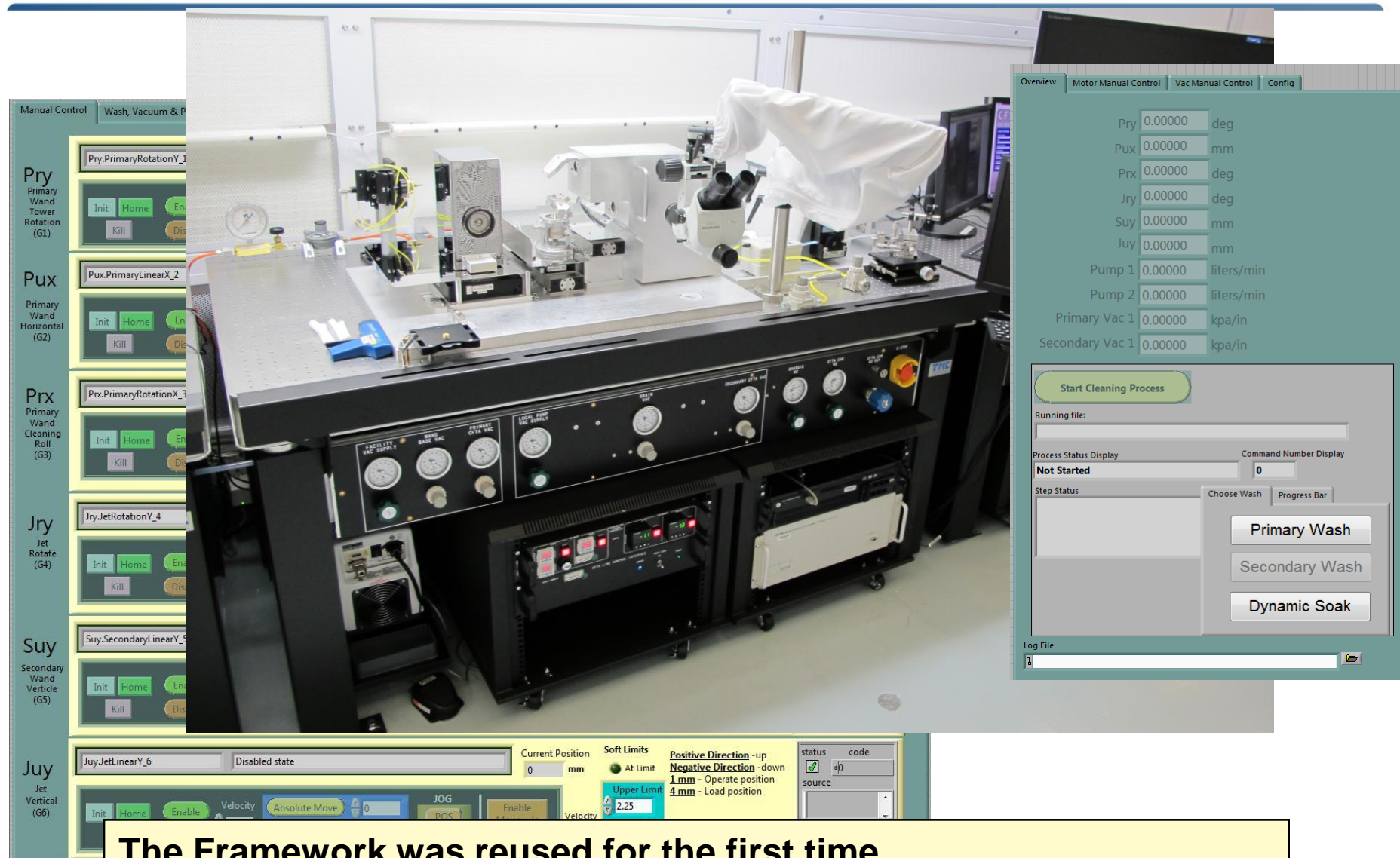
The screenshot shows the CFTA Mapper software interface. The title bar reads "CFTA Mapper". The main window has a header with "CFTA Mapper" in large letters, "Operator: TestDS" in a blue box, and "Data Upload" in a blue box. Below the header are buttons for "Map", "Load", and "Unload". The "Mapping Recipe" section shows "Acquisition Progress" at 160 of 160 and "Processing Progress" at 125 of 160. The "Current Settings" section shows "Data Set Name" as "TestDS", "Site" as "NIF", and "Component Type". The "secondaryHighMag" section shows a table of patch data.

Selected	Patch Num.	X	Y	How Many	Patch Name	Submitted	
<input type="checkbox"/>	107	184.217	86.6218	1	1	CFTA_99999_107_XM_184_Y	Completed_NoError
<input type="checkbox"/>	108	184.217	173.244	1	1	CFTA_99999_108_XM_184_Y	Completed_NoError
<input type="checkbox"/>	109	184.217	259.865	1	1	CFTA_99999_109_XM_184_Y	Completed_NoError
<input type="checkbox"/>	110	184.217	346.487	1	1	CFTA_99999_110_XM_184_Y	Completed_NoError
<input type="checkbox"/>	111	184.217	433.109	1	1	CFTA_99999_111_XM_184_Y	Completed_NoError
<input type="checkbox"/>	112	184.217	519.731	1	1	CFTA_99999_112_XM_184_Y	Completed_NoError
<input type="checkbox"/>	113	184.217	606.353	1	1	CFTA_99999_113_XM_184_Y	Completed_NoError
<input type="checkbox"/>	114	184.217	692.975	1	1	CFTA_99999_114_XM_184_Y	Completed_NoError
<input type="checkbox"/>	115	184.217	779.597	1	1	CFTA_99999_115_XM_184_Y	Completed_NoError
<input type="checkbox"/>	116	184.217	866.218	1	1	CFTA_99999_116_XM_184_Y	Completed_NoError
<input type="checkbox"/>	117	184.217	952.840	1	1	CFTA_99999_117_XM_184_Y	Completed_NoError
<input type="checkbox"/>	118	184.217	1039.462	1	1	CFTA_99999_118_XM_184_Y	Completed_NoError
<input type="checkbox"/>	119	184.217	1126.084	1	1	CFTA_99999_119_XM_184_Y	Completed_NoError
<input type="checkbox"/>	120	184.217	1212.706	1	1	CFTA_99999_120_XM_184_Y	Completed_NoError
<input type="checkbox"/>	121	184.217	1299.328	1	1	CFTA_99999_121_XM_184_Y	Completed_NoError
<input type="checkbox"/>	122	184.217	1385.950	1	1	CFTA_99999_122_XM_184_Y	Completed_NoError
<input type="checkbox"/>	123	184.217	1472.572	1	1	CFTA_99999_123_XM_184_Y	Completed_NoError
<input type="checkbox"/>	124	184.217	1559.194	1	1	CFTA_99999_124_XM_184_Y	Completed_NoError
<input type="checkbox"/>	125	184.217	1645.816	1	1	CFTA_99999_125_XM_184_Y	Completed_NoError
<input type="checkbox"/>	126	184.217	1732.438	1	1	CFTA_99999_126_XM_184_Y	Completed_NoError
<input type="checkbox"/>	127	184.217	1819.060	1	1	CFTA_99999_127_XM_184_Y	Completed_NoError
<input type="checkbox"/>	128	184.217	1905.682	1	1	CFTA_99999_128_XM_184_Y	Completed_NoError
<input type="checkbox"/>	129	184.217	1992.304	1	1	CFTA_99999_129_XM_184_Y	Completed_NoError
<input type="checkbox"/>	130	184.217	2078.926	1	1	CFTA_99999_130_XM_184_Y	Completed_NoError
<input type="checkbox"/>	131	184.217	2165.548	1	1	CFTA_99999_131_XM_184_Y	Completed_NoError
<input type="checkbox"/>	132	184.217	2252.170	1	1	CFTA_99999_132_XM_184_Y	Completed_NoError
<input type="checkbox"/>	133	184.217	2338.792	1	1	CFTA_99999_133_XM_184_Y	Completed_NoError
<input type="checkbox"/>	134	184.217	2425.414	1	1	CFTA_99999_134_XM_184_Y	Completed_NoError
<input type="checkbox"/>	135	184.217	2512.036	1	1	CFTA_99999_135_XM_184_Y	Completed_NoError
<input type="checkbox"/>	136	184.217	2598.658	1	1	CFTA_99999_136_XM_184_Y	Completed_NoError
<input type="checkbox"/>	137	184.217	2685.280	1	1	CFTA_99999_137_XM_184_Y	Completed_NoError
<input type="checkbox"/>	138	184.217	2771.902	1	1	CFTA_99999_138_XM_184_Y	Completed_NoError
<input type="checkbox"/>	139	184.217	2858.524	1	1	CFTA_99999_139_XM_184_Y	Completed_NoError
<input type="checkbox"/>	140	184.217	2945.146	1	1	CFTA_99999_140_XM_184_Y	Completed_NoError
<input type="checkbox"/>	141	184.217	3031.768	1	1	CFTA_99999_141_XM_184_Y	Completed_NoError
<input type="checkbox"/>	142	184.217	3118.390	1	1	CFTA_99999_142_XM_184_Y	Completed_NoError
<input type="checkbox"/>	143	184.217	3205.012	1	1	CFTA_99999_143_XM_184_Y	Completed_NoError
<input type="checkbox"/>	144	184.217	3291.634	1	1	CFTA_99999_144_XM_184_Y	Completed_NoError
<input type="checkbox"/>	145	184.217	3378.256	1	1	CFTA_99999_145_XM_184_Y	Completed_NoError
<input type="checkbox"/>	146	184.217	3464.878	1	1	CFTA_99999_146_XM_184_Y	Completed_NoError
<input type="checkbox"/>	147	184.217	3551.500	1	1	CFTA_99999_147_XM_184_Y	Completed_NoError
<input type="checkbox"/>	148	184.217	3638.122	1	1	CFTA_99999_148_XM_184_Y	Completed_NoError
<input type="checkbox"/>	149	184.217	3724.744	1	1	CFTA_99999_149_XM_184_Y	Completed_NoError
<input type="checkbox"/>	150	184.217	3811.366	1	1	CFTA_99999_150_XM_184_Y	Completed_NoError
<input type="checkbox"/>	151	184.217	3897.988	1	1	CFTA_99999_151_XM_184_Y	Completed_NoError
<input type="checkbox"/>	152	184.217	3984.610	1	1	CFTA_99999_152_XM_184_Y	Completed_NoError
<input type="checkbox"/>	153	184.217	4071.232	1	1	CFTA_99999_153_XM_184_Y	Completed_NoError
<input type="checkbox"/>	154	184.217	4157.854	1	1	CFTA_99999_154_XM_184_Y	Completed_NoError
<input type="checkbox"/>	155	184.217	4244.476	1	1	CFTA_99999_155_XM_184_Y	Completed_NoError
<input type="checkbox"/>	156	184.217	4331.098	1	1	CFTA_99999_156_XM_184_Y	Completed_NoError
<input type="checkbox"/>	157	184.217	4417.720	1	1	CFTA_99999_157_XM_184_Y	Completed_NoError
<input type="checkbox"/>	158	184.217	4504.342	1	1	CFTA_99999_158_XM_184_Y	Completed_NoError
<input type="checkbox"/>	159	184.217	4590.964	1	1	CFTA_99999_159_XM_184_Y	Completed_NoError
<input type="checkbox"/>	160	184.217	4677.586	1	1	CFTA_99999_160_XM_184_Y	Completed_NoError

The photograph shows the experimental setup with a confocal microscope and a computer workstation. A "Caution FRAGILE" sign is visible on the equipment.

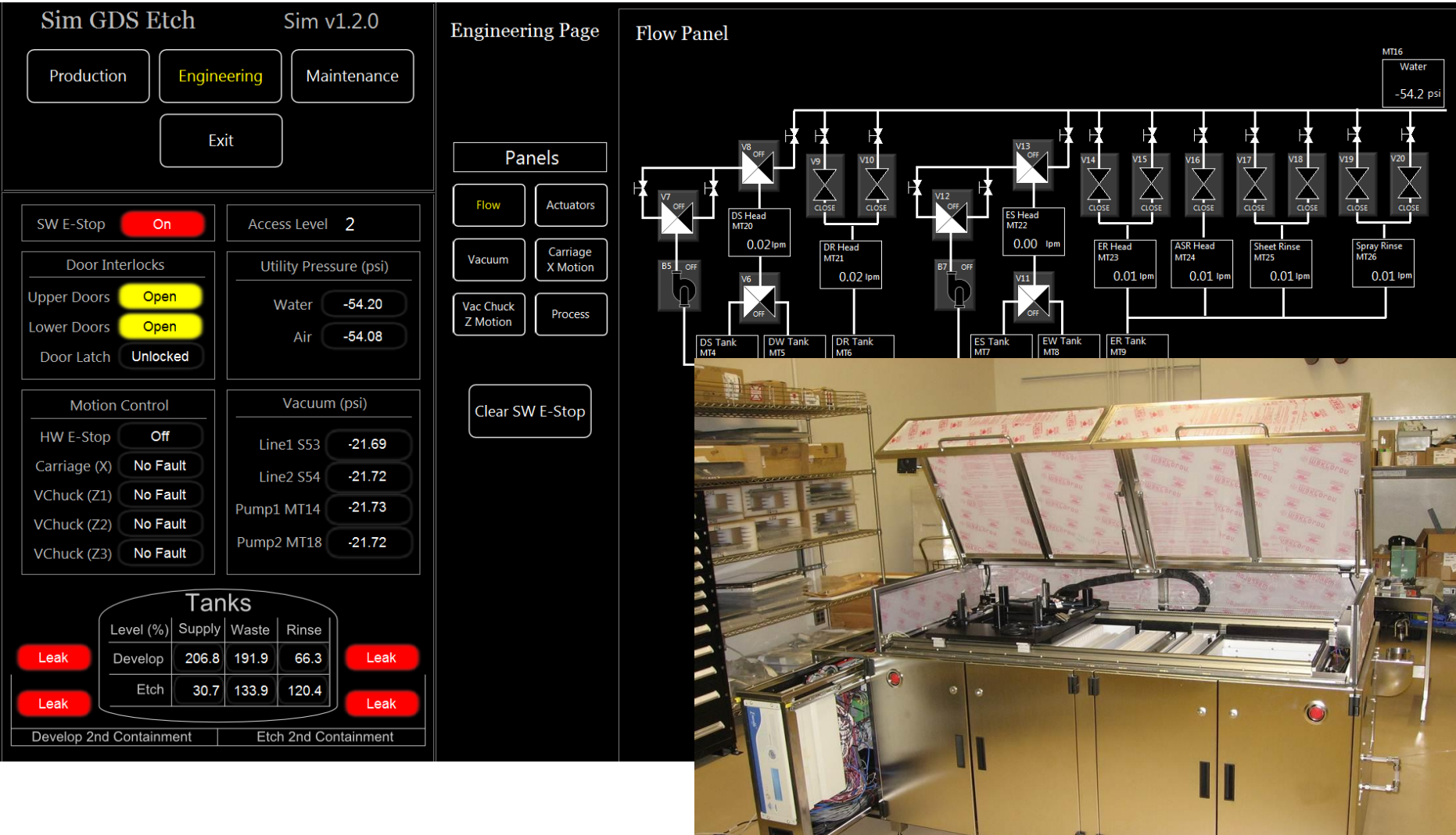
**A 'core' Framework was designed and implemented.
The team was trained in OO and introduced to best practices.**

The CFTA Cleaning station cleans capsules to improve performance.



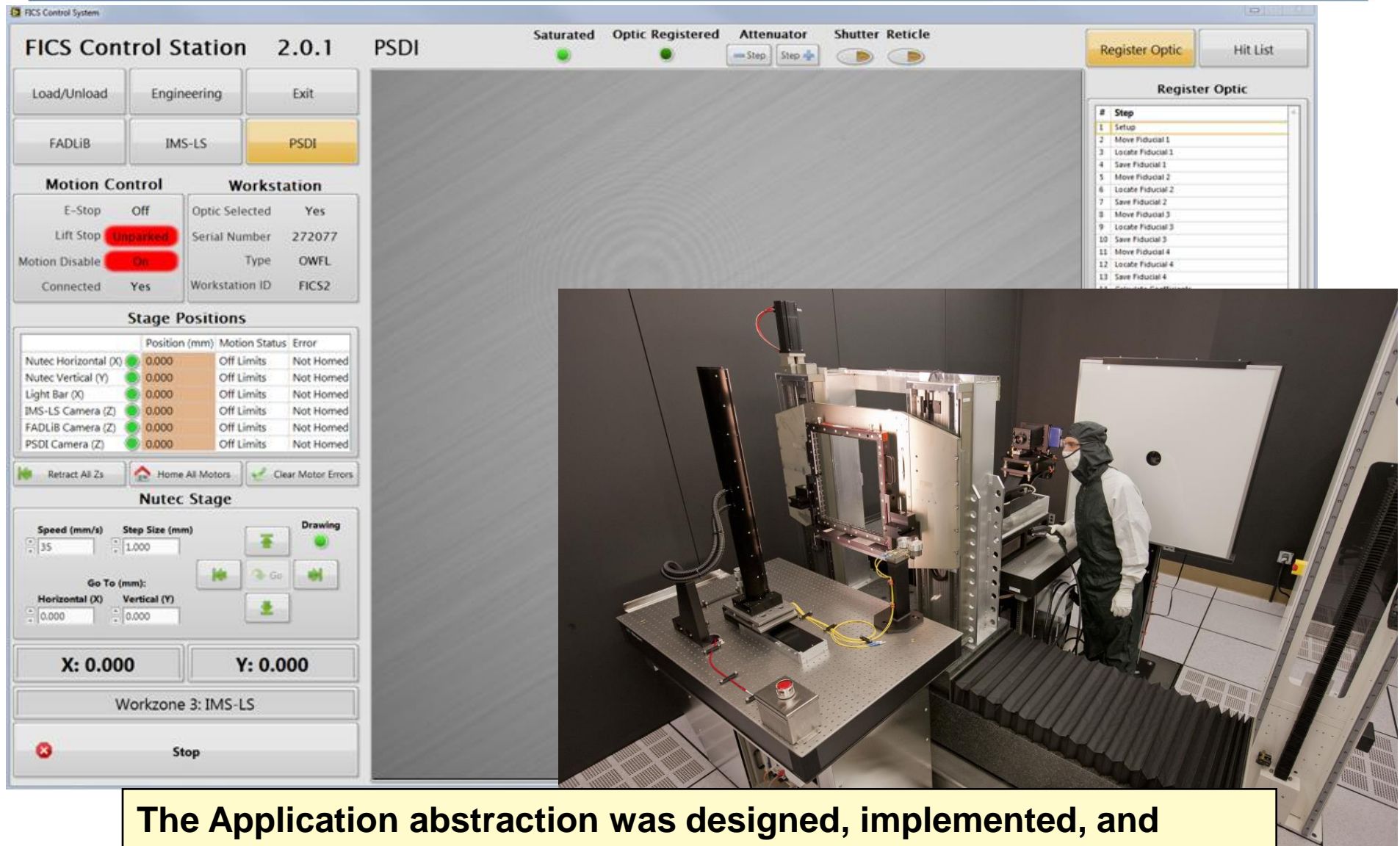
The Framework was reused for the first time, and evolved to meet new requirements and lessons learned.

The Etching station develops and etches Grating Debris Shield optics.



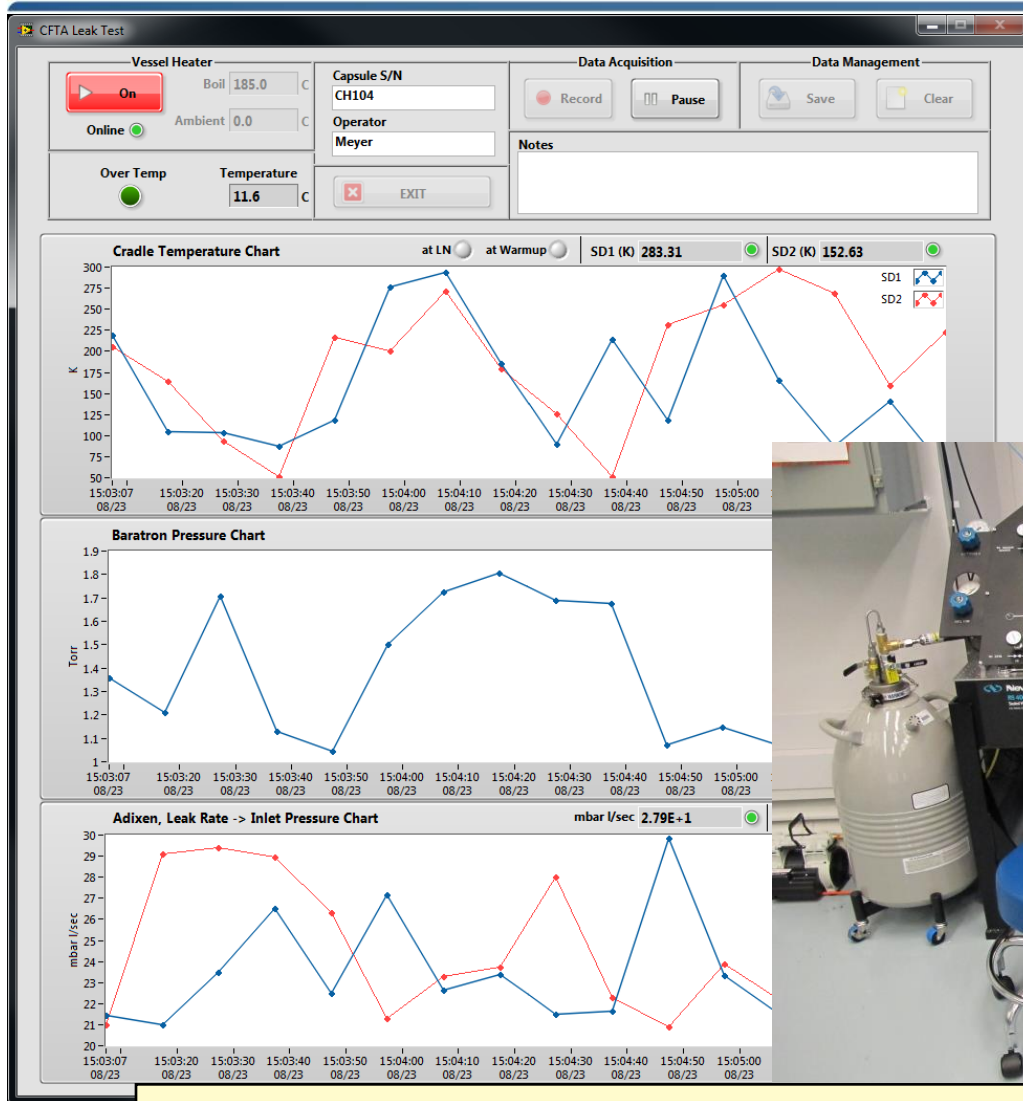
The GUI and Recipe abstractions were designed, implemented, and added to the Framework.

The Flaw Identification and Characterizations Station (FICS) characterizes optic flaws.



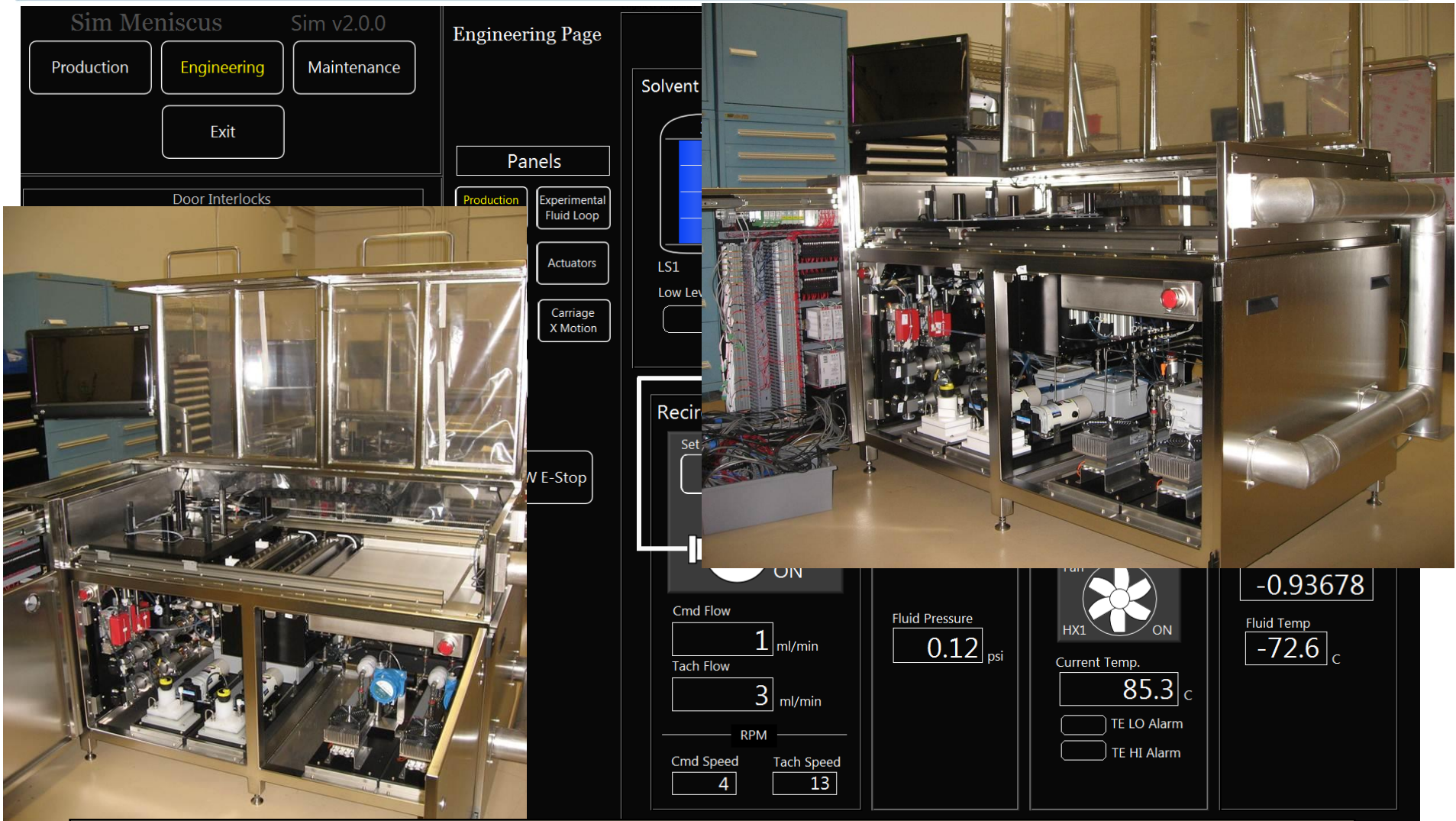
The Application abstraction was designed, implemented, and added to the Framework, the GUI abstractions were refined.

CFTA Leak Test station quantifies capsule integrity.



RS232 Communication and Protocol abstractions were added to the Framework.

Meniscus coaters apply PhotoResist or SolGel to optics.



**The Frameworks and GDS Etch were heavily reused.
The systems completed in record time.**

The ARC Transporter installs/removes AM6, AM7, and AM8 LRUs in the target bay's parabola vessel.

THARCTSGUI.lvclass:display.vi:1 (clone)

ESTOP
OVERRIDE
cRIO COMM
RESET
LOW

LRU Frame: AM6
Procedure: Install
Current State: AM6I_FRH_MFHH

Previous
Next

0) Scissors Fully Retracted to F
1) Scissors Fully Retracted to Vertice
2) Vertical Rail Removal to Staging F

Load Cells Target

MT44	MT46
1871	1876
Sum	7498
MT43	MT45
1874	1877

Tug

CV1 KM
EXT RET

CV2 KM
RET EXT

AM6

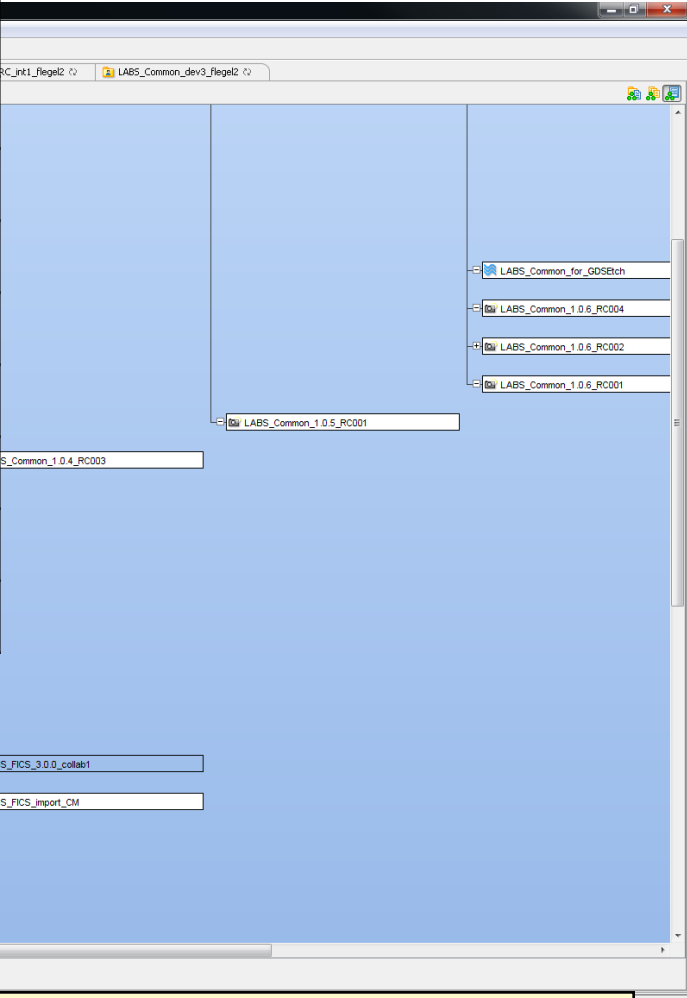
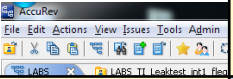
Drive: Disabled
Up: Disabled 0 0 Disabled
Down

THARC.lvproj/My Com

The Communication abstraction was upgraded, and Network Streams were added to the Framework.

These systems are under configuration management and have something in *Common* ...

	<u>System Version</u>	<u>Common Version</u>
CFTA Mapping	1.1.0	1.0.7.RC002
CFTA Cleaning	1.1.0	1.0.3.RC002
GDS Etch	2.0.0	1.0.6.RC004
FICS	2.0.2	1.0.4.RC003
CFTA Leaktest	1.1.0	1.0.6.RC003
PR Coater	2.0.0	1.0.6.RC004
SolGel Coater	2.0.0	1.0.6.RC004
TH ARC	1.0.0	1.0.7.RC002



These systems are built from various releases of the same *Common Framework*.

Each system uses the *Common Framework*.

	Total		Reuse	
	Classes	Methods	Classes	Methods
CFTA Mapping	131	1098	66%	59%
CFTA Cleaning	83	611	80%	83%
GDS Etch	143	1331	58%	53%
FICS	173	1166	60%	68%
CFTA Leaktest	173	1166	60%	68%
PR Coater	83	652	70%	67%
SolGel Coater	161	1110	65%	71%
TH ARC	116	883	65%	75%
Average	132.9	1002.1	64%	66%

On average, 85 classes (including 665 methods) are reused.

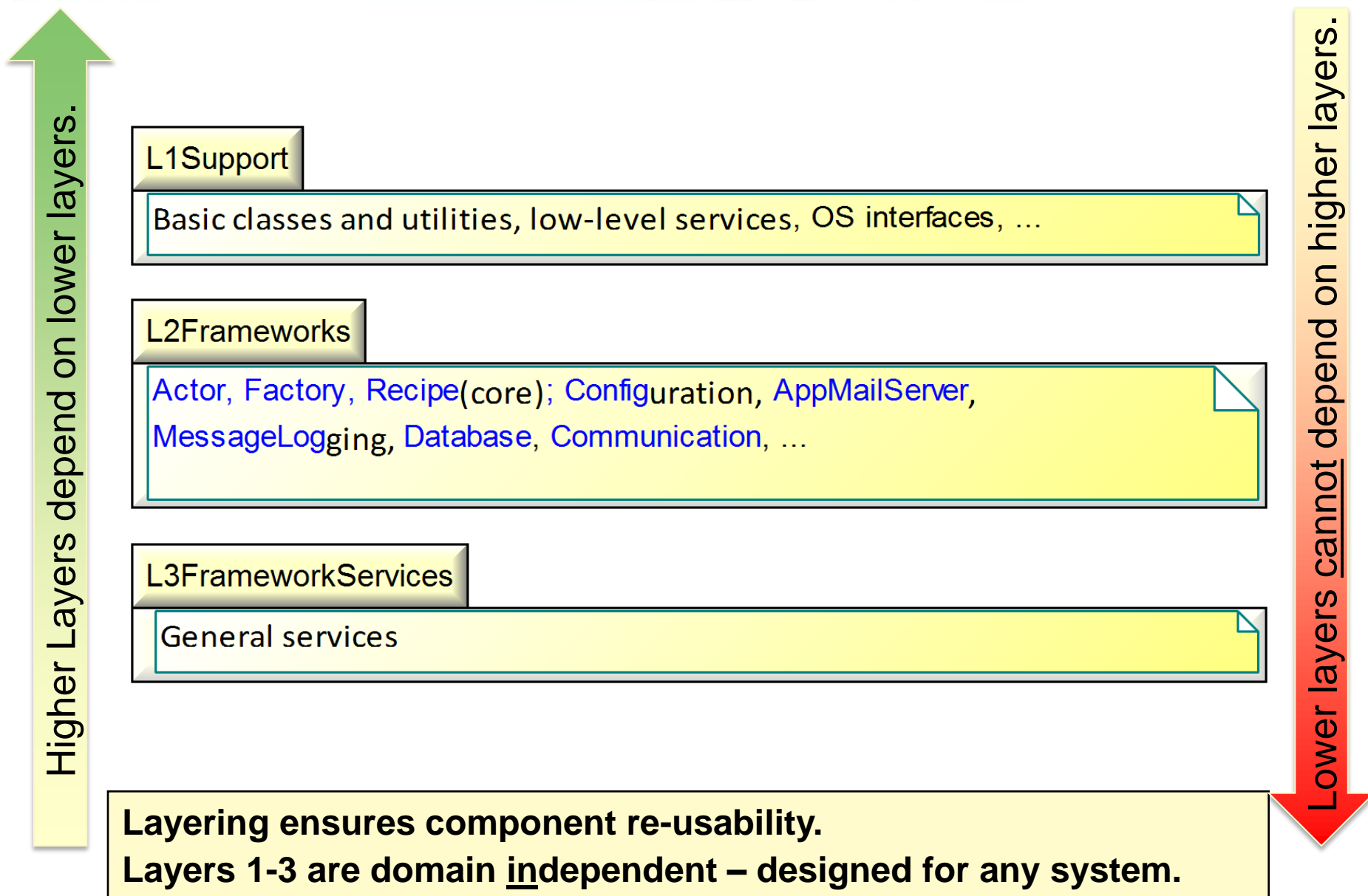
Why did we do this?

- **OMF was a successful project:**
 - Completed in 15 months, 1/3rd the Java/C++ estimate
 - Applied software engineering best practices
 - Relied on LabVIEW's built-in GUI and hardware support
 - Focus of a highly respected NI case study
- **All systems have something in common, they:**
 - Control devices (drive motors, toggle switches)
 - Collect data (take pictures, generate signals)
 - Interact with the User / Operator
- **So we created this Common, reuseable Framework**
 - Used by all systems
 - Implemented with Best Practices
 - Designed, Coded, Tested
 - Configuration Managed

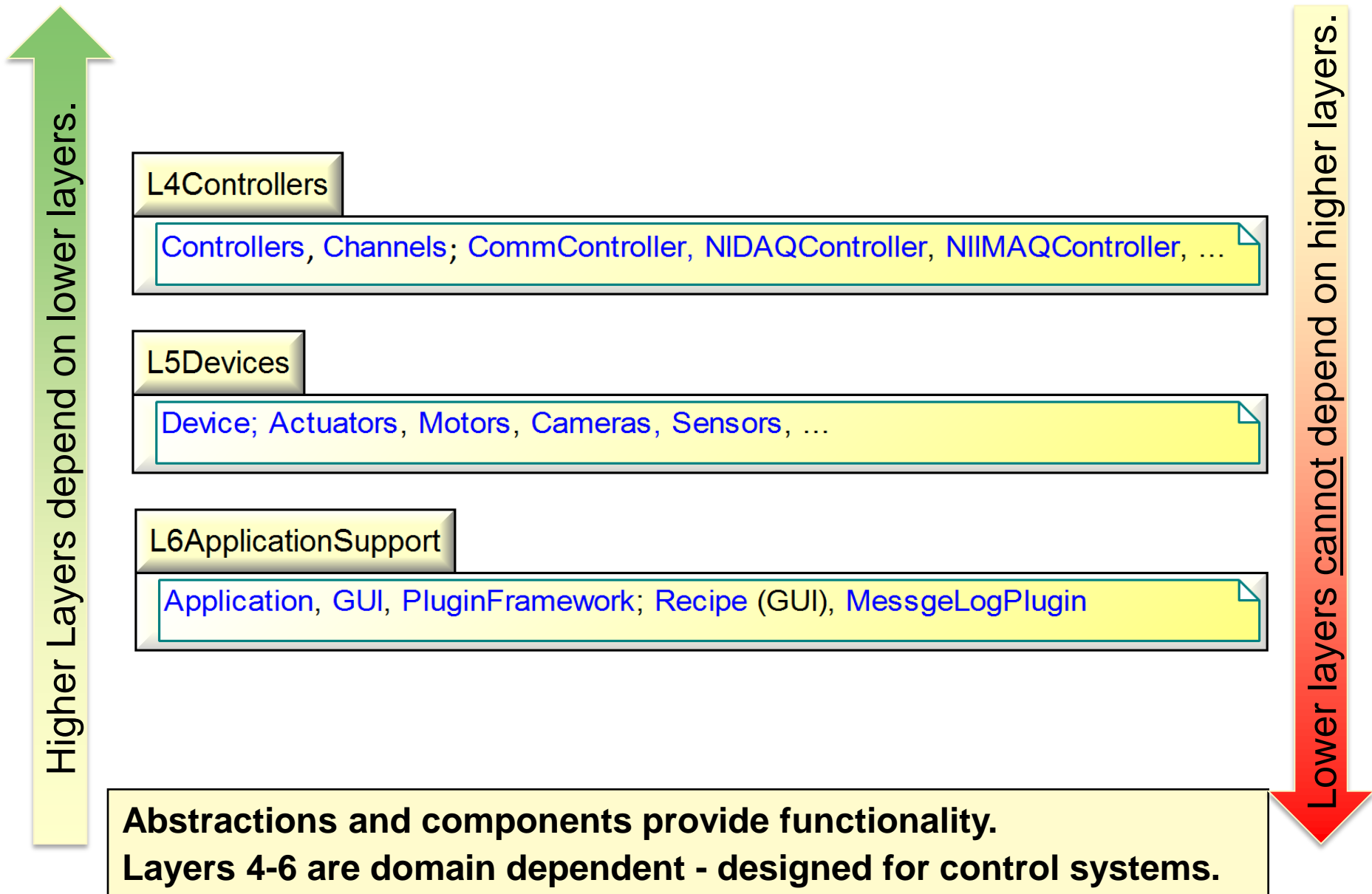
**Reused code is 'free' – already developed, already tested.
Reused code is 'consistent' – architecture, look & feel.**

What is the Framework?

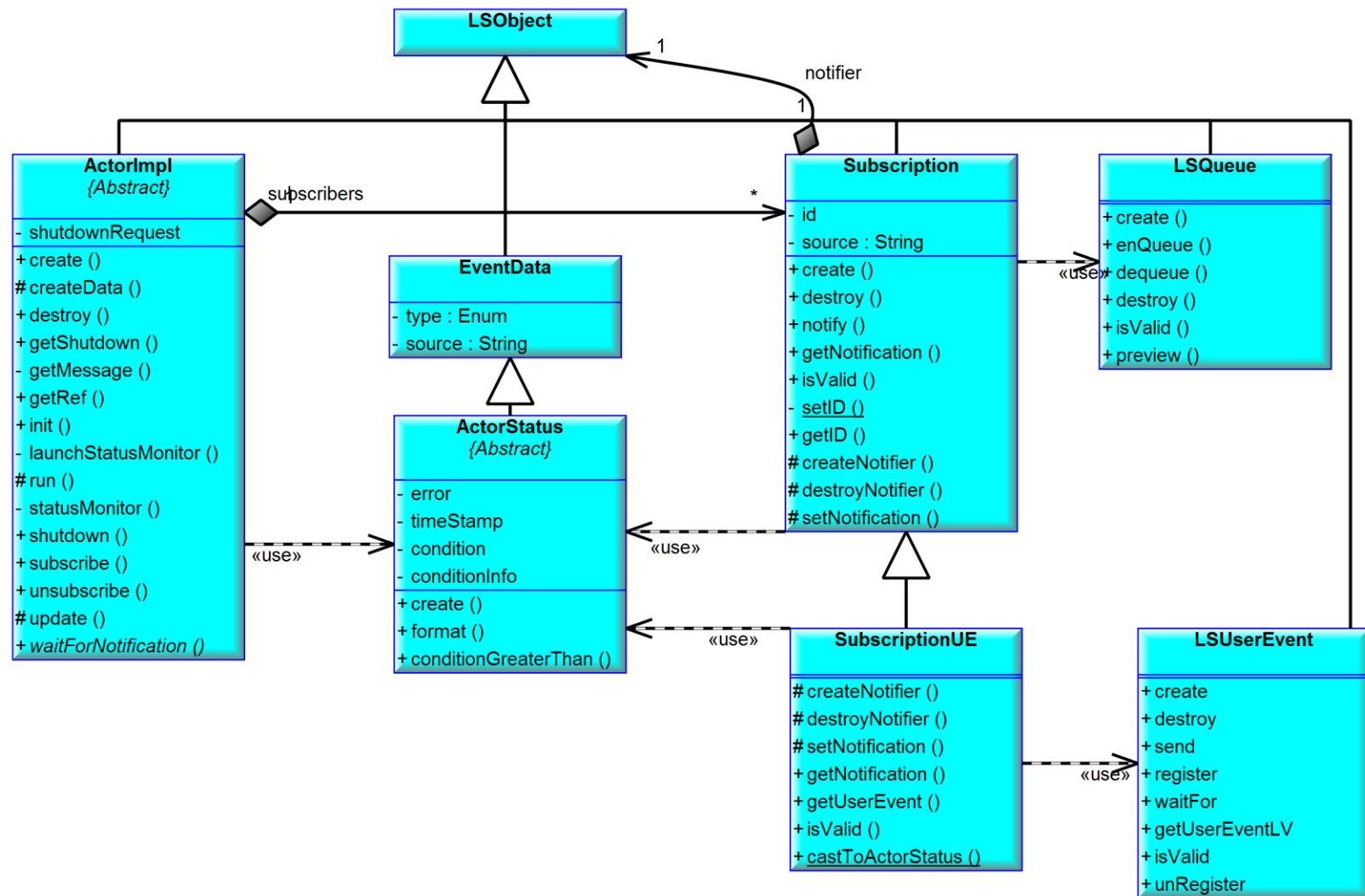
... Code layering, and ...



... abstractions and components.

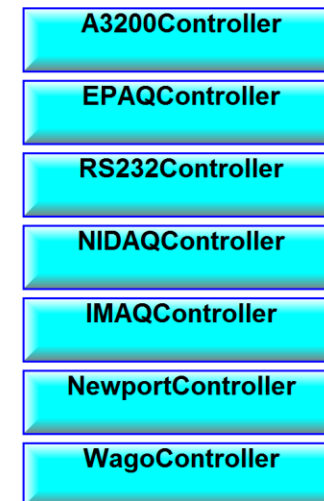
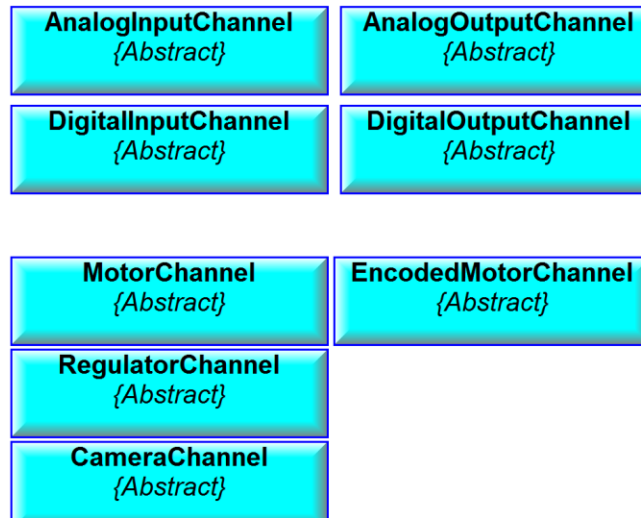
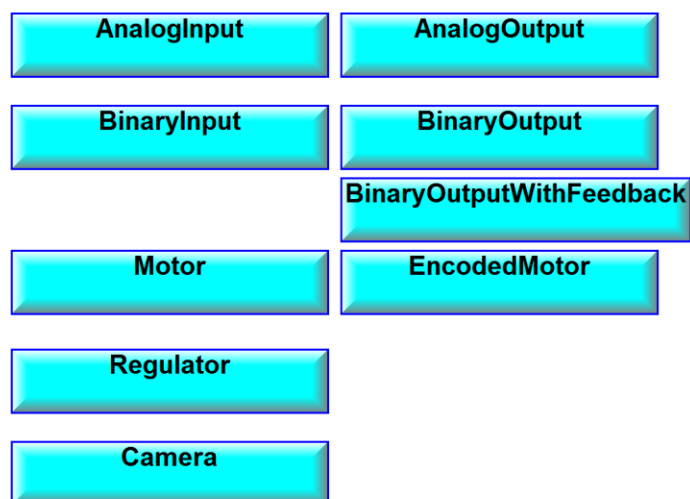
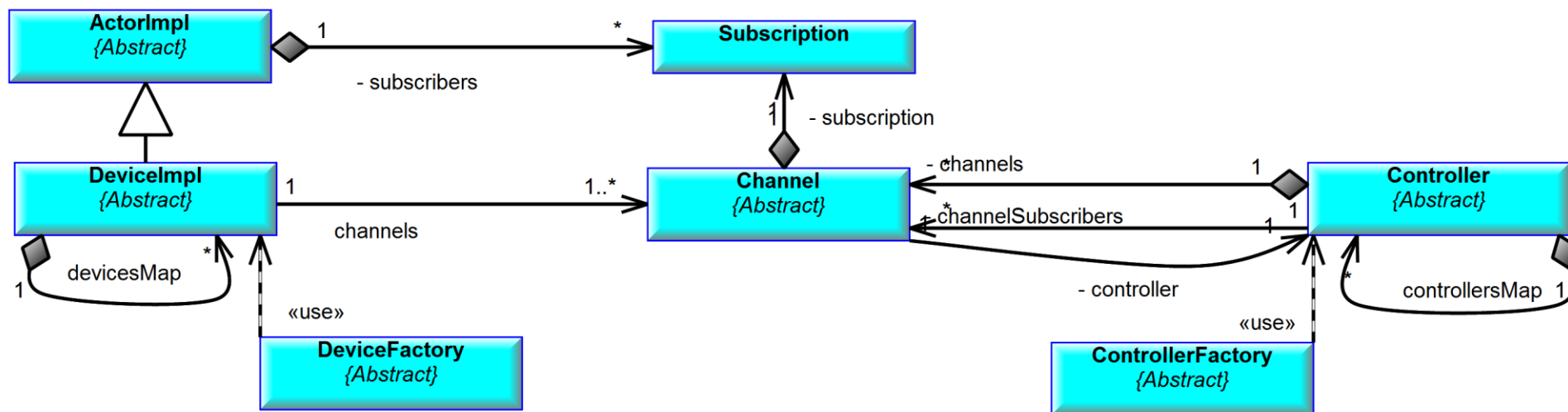


Designed and implemented in Object Oriented LabVIEW.



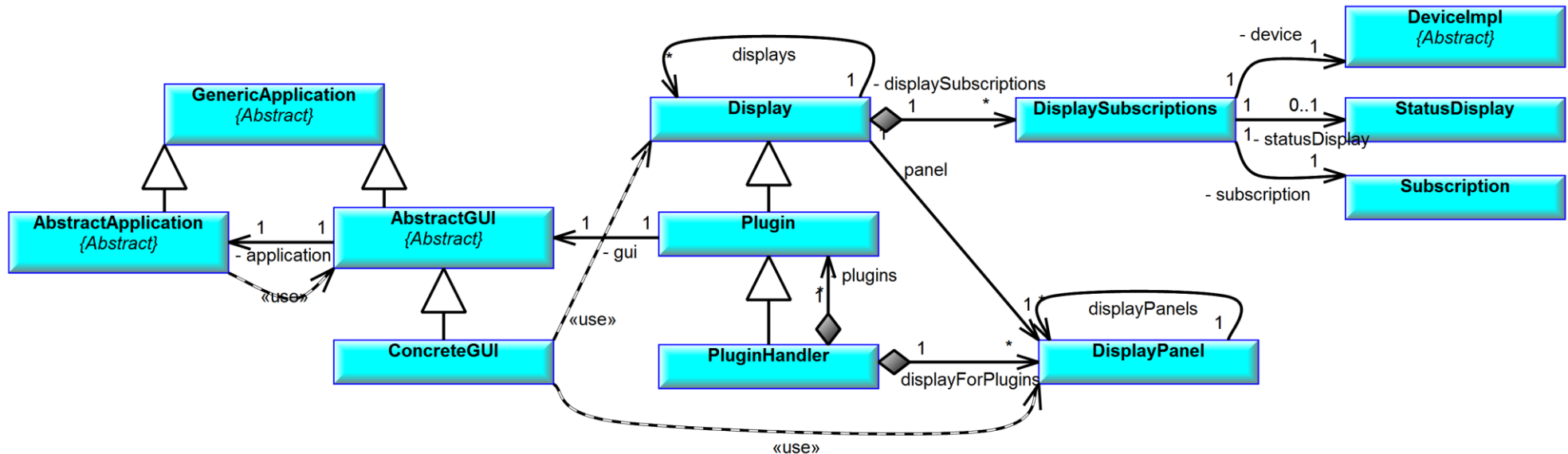
The Actor is the core of the Supervisory control and Hardware abstraction.

The Device / Channel / Controller classes are the core of Common hardware abstraction.



The hardware interface implementation is hidden from the device modeling.

The Application and GUI classes are the core of Common user interface capabilities.



Common displays can be created, shared between applications, and provide consistent look & feel.

What perceptions and concerns were encountered along the way?

- LabVIEW applications are ‘sub-standard’ and unstable for production.
 - ⇒ It’s how LabVIEW is applied, not LabVIEW itself.
- Why is it taking sooooo long?
 - ⇒ Early systems absorbed the cost for creating the Framework
 - ⇒ We evolved to a more agile development process.
 - ⇒ Deliver manual control of the machine,
... then add features.
- You implemented what I asked for, but that’s not what I want!
 - ⇒ Requirements analysis includes GUI prototyping.
 - ⇒ Deliver manual control of the machine,
... then add features.
- Individuals had their own software ‘toolbox’.
 - ⇒ We have a shared toolbox the whole team understands.

**Software was audited and meets ‘DOE Order 414.1D’ for Risk Level 3.
LabVIEW can be used to develop robust, re-usable software.**

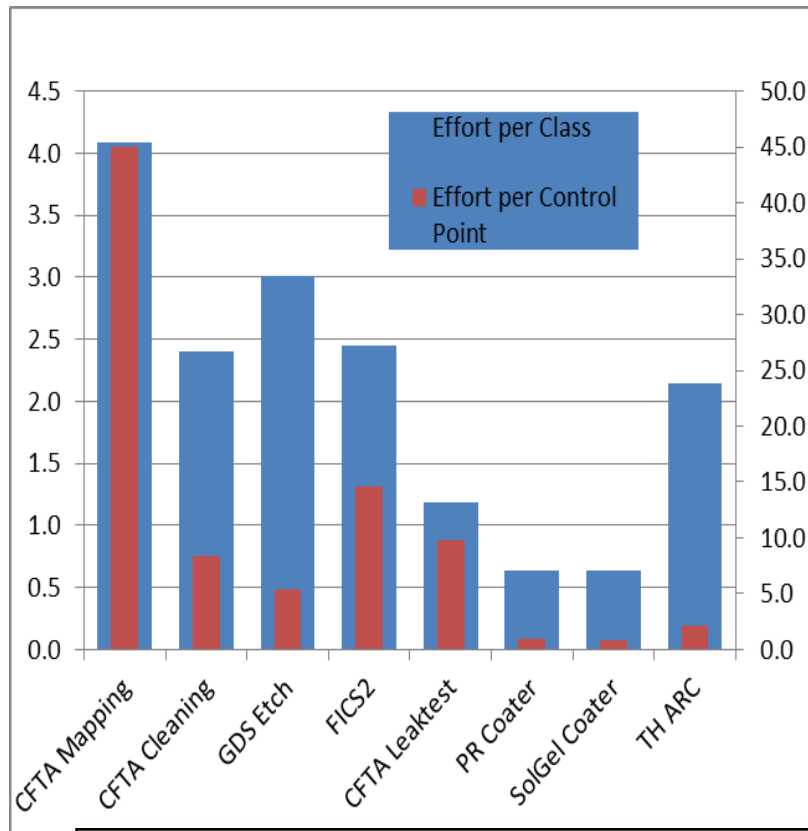
How did we do this?

- **Formed and Trained the team:**
 - **Object Oriented Design & Programming**
 - **Configuration Management**
 - Change management ([Jira](#)), Source Code Control ([AccuRev](#))
 - TUCOBAB03: "Utilizing Atlassian JIRA for Large-Scale Software Development Management"
- **Performed Software Engineering**
 - **Software project planning**
 - tasks, estimates, schedules, communication, requirements management
 - **Requirements Analysis**
 - **Code Reviews**
 - **Independent Testing**
- **Designed for reuse**
 - **Focus on system design, with reuse in mind**
 - **Abstractions and Components refactored into Common when needed and/or mature for reuse**
- **Implemented in LabVIEW**

The team is performing and we are reaping rewards.

How well are we doing?

- Each system builds on improvements from earlier systems.
- The cost to build each system is trending downward.



		Effort (d) Total	Effort (d) per Class	Effort (d) per Control Point	Control Points (Devices & Controllers)
1	CFTA Mapping	585	4.1	45.0	13
2	CFTA Cleaning	199	2.4	8.3	24
3	GDS Etch	486	3.0	5.3	91
4	FICS2	321	2.5	14.6	22
5	CFTA Leaktest	98	1.2	9.8	10
6	PR Coater	109	0.6	0.9	119
7	SolGel Coater	109	0.6	0.9	123
8	TH ARC	249	2.1	2.1	120

**‘These are some of the most stable systems we [customers] have seen.’
National Instruments is taking a keen interest in what we are doing.**

What next?

- **Continually improve**
 - **Agile development**
 - **Framework packaging**
 - **Encourage developers to enhance their skills**
 - **Training & Certification**
- **Rapid Prototyping**
 - **Some customers need applications running 'today'**
 - **Support fast prototyping**
- **Communication**
 - **Advertise and interact with the community**

NIF

