

Appendix G

Transition to Operations Plan



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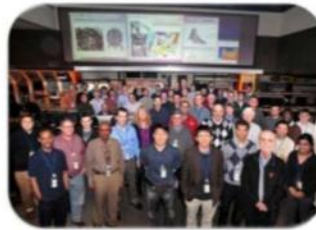
Office of Science

Transition to Research on NSTX-U

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Columbia U
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U Wisconsin
X Science LLC

Stefan Gerhardt
Research Staff
Head of Experimental Research Operations

**NSTX-U CD-4 Closeout
B-318
September 2nd, 2015**



Culham Sci Ctr
York U
Chubu U
Fukui U
Hiroshima U
Hyogo U
Kyoto U
Kyushu U
Kyushu Tokai U
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CEA, Cadarache
IPP, Jilich
IPP, Garching
ASCR, Czech Rep

Outline

- NSTX-U scientific goals
- NSTX-U CD-4 plasma results
- NSTX-U organization
- Outline of the first experimental campaign

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Five Year Plan Described Five Highest Priority Research Goals

Present Upgrade

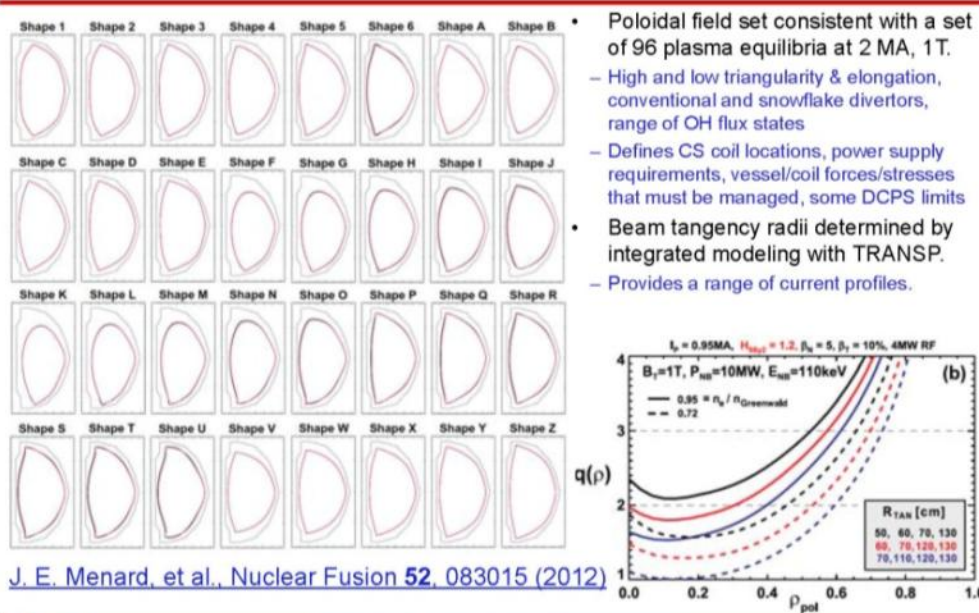
Future Upgrade (See Backup Slides)

- 1. Demonstrate 100% non-inductive sustainment at performance that extrapolates to $\geq 1\text{MW/m}^2$ neutron wall loading in FNSF**
 - 2nd neutral beam, higher TF
 - Cryopump (future upgrade), NCC (future upgrade)
- 2. Access reduced ν^* and high- β combined with ability to vary q and rotation to dramatically extend ST physics understanding**
 - 2nd neutral beam, higher TF, higher I_p
 - Cryopump (future upgrade), NCC (future upgrade)
- 3. Develop and understand non-inductive start-up and ramp-up (overdrive) to project to ST-FNSF with small/no solenoid**
 - 2nd neutral beam, higher TF
 - ECH (future upgrade)
- 4. Develop and utilize high-flux-expansion “snowflake” divertor and radiative detachment for mitigating very high heat fluxes**
 - Expanded PF-1 coil set, new divertor gas injectors
- 5. Begin to assess high-Z PFCs + liquid lithium to develop high-duty-factor integrated PMI solutions for next-steps**
 - Metal PFCs and flowing lithium systems (future upgrades)

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Transition to Operations Plan (continued)

Engineering Design Driven By Physics Considerations



J. E. Menard, et al., Nuclear Fusion 52, 083015 (2012)


Long-Term Research Agenda For NSTX-U is Defined in the 5-Year Plan

- Available on the web at:
- <http://nstx-u.pppl.gov/five-year-plan/five-year-plan-2014-18>
- 11 Chapters, written by the entire NSTX-U team, describing
 - the research goals
 - future upgrades to the facility
- Reviewed over three days in May 2013.
- Accepted by DoE.

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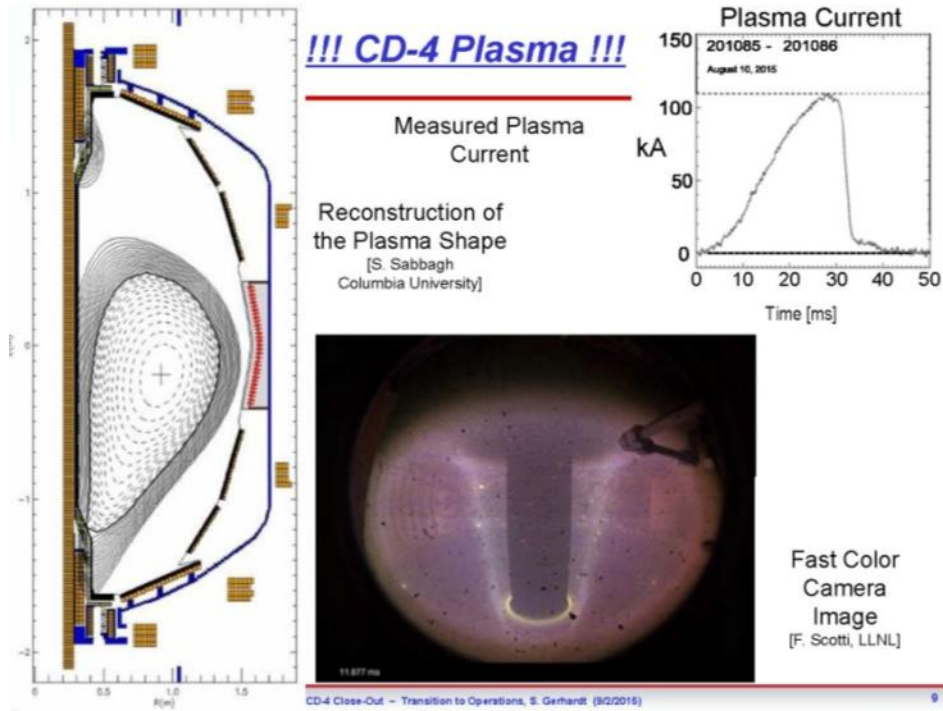
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CD-4 Run-Up

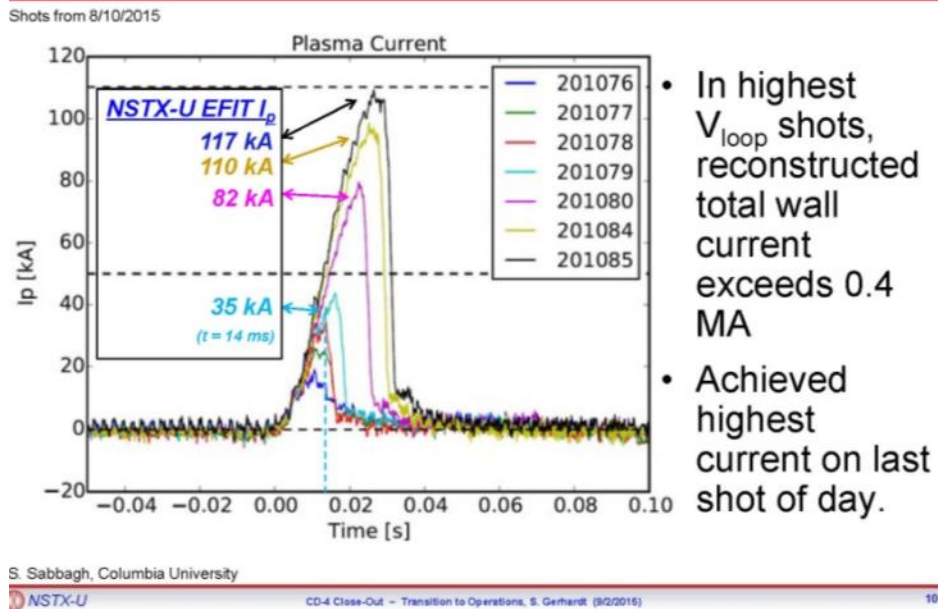
- **[8/3/2015]** ES&H Executive Board accepted the ACC recommendation to restart the facility.
- **[8/4/2015]** Begin the coil system Integrated Systems Test Procedure (ISTP-001)
 - [8/4/2015] Complete Coil High-Pots
 - [8/5/2015-8/7/2015] Single Coil Test Shots
 - [8/10/2015] Combined Field Test Shots
- **[8/10/2015]** Begin plasma operations under XMP-100.
 - Achieve 100 kA of plasma current
- **[8/11/2015 & 8/12/2015]** Continued operation on XMP-130.
 - Achieve ~140 kA, improve plasma positioning.

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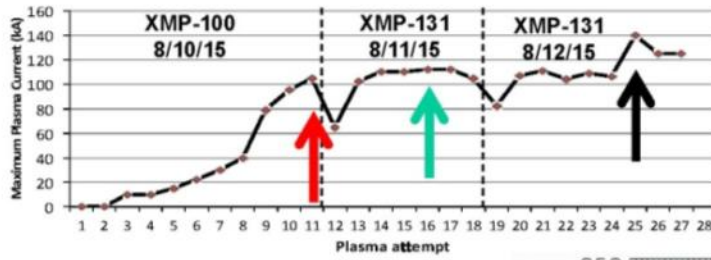
Measured, compensated plasma current compares well to NSTX-U EFIT reconstructed current on CD-4 day.



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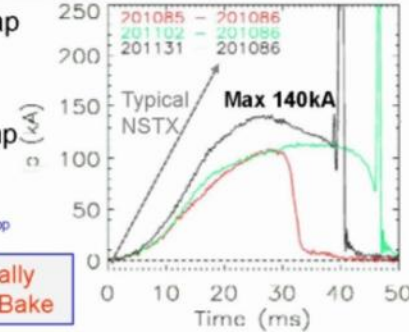
Continued Improvement in Plasma Current and Duration in Sixteen Plasma Shots over 1.5 Days



(27 out of 29 attempts were "good" over 2 days)

(First shot after morning He glow takes a hit)

- Centering plasma and shrinking outer gap lengthened discharge (Tues)
 - Larger PF3/PF5 improves vertical stability
 - Modest improvement in max I_p
- Reducing prefill fueling increased I_p ramp rate (Wed)
 - Increased maximum $I_p \sim 135 - 140$ kA
 - More importantly, would allow reduction in V_{loop}



Performance Should be Dramatically Better Once We do the Full Vessel Bake

D. Battaglia, PPPL
NSTX-U

CD-4 Close-Out - Transition to Operations, S. Gerhardt (9/2/2015)

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NSTX-U

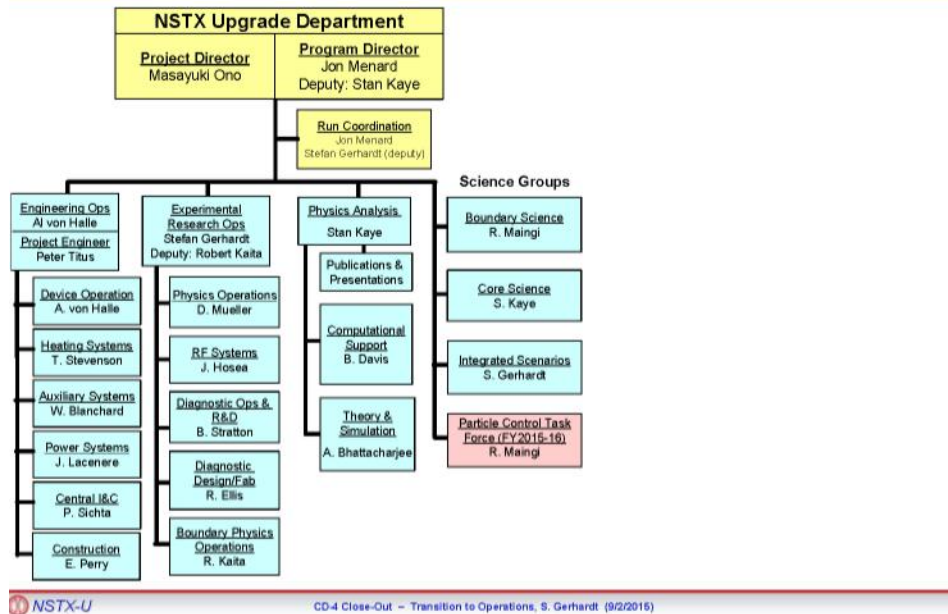
CD-4 Close-Out - Transition to Operations, S. Gerhardt (9/2/2015)

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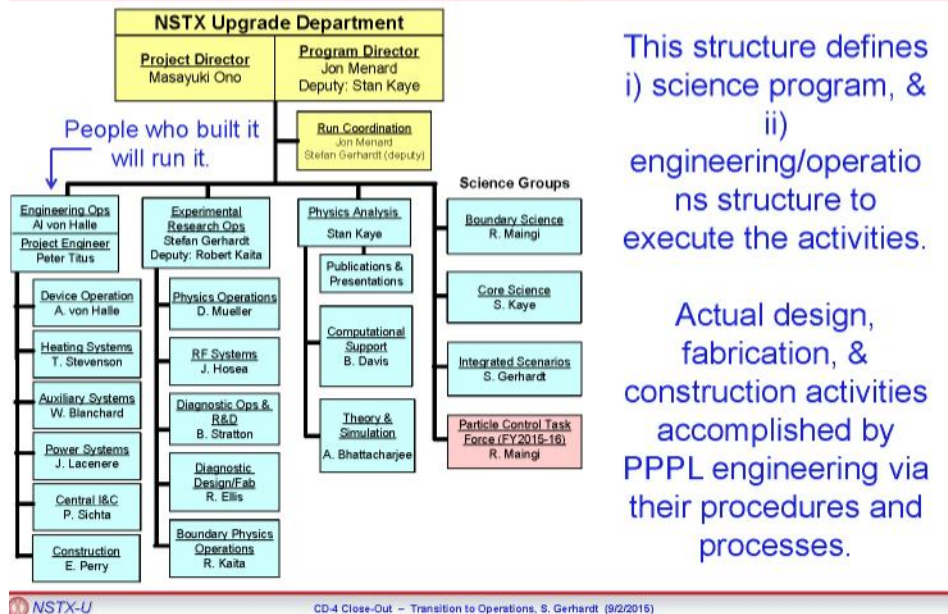
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Transition to Operations Plan (continued)

NSTX-U Experimental Program Organizational Structure is Clearly Defined



NSTX-U Experimental Program Organizational Structure is Clearly Defined



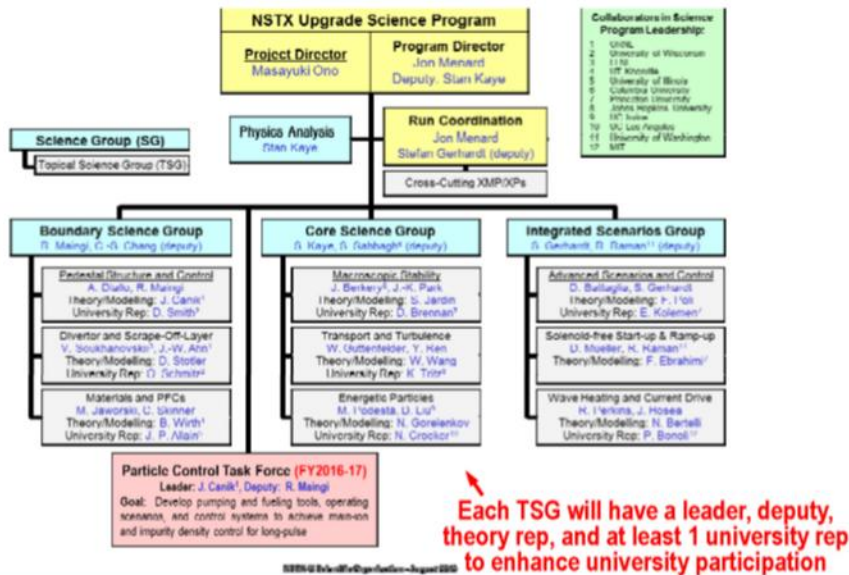
This structure defines
 i) science program, &
 ii) engineering/operations structure to execute the activities.

Actual design, fabrication, & construction activities accomplished by PPPL engineering via their procedures and processes.

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Transition to Operations Plan (continued)

NSTX-U Research Program Is Organized Along 3 “Science Groups” and 9 TSGs for the FY15 run



Many Non-Upgrade Tasks Have Been Undertaken to Prepare for the Run

- Crucial diagnostics
 - Many upgrades to the magnetic diagnostics
 - Large changes to the critical Thomson scattering systems successfully implemented
 - All major profile diagnostics installed and calibrated.
 - Many new or upgraded diagnostics...
- Upgrades to the High Harmonic Fast Wave (HHFW) antenna.
- New boronization systems with improved safety features.
- New plasma control computers and many algorithm upgrades

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Transition to Operations Plan (continued)

Daily Operations Directed by Experimental Proposals (XPs) and Experimental Machine Proposals (XMPs)

- | XPs | XMPs |
|--|---|
| <ul style="list-style-type: none">• Describe experiments to answer science questions• Governed by OP-ADX-03• Reviewed by<ul style="list-style-type: none">– topical science group– run coordinator• Typically described 1/2-2 days of machine operations• Expectation that that each XP will lead to a publishable result | <ul style="list-style-type: none">• Describe experiments to qualify new machine capabilities• Governed by OP-ADX-02• Reviewed by<ul style="list-style-type: none">– physics operations branch head– research operations division head• Typically describe ½ -1 day of machine operations• Expectation is that each XMP will facilitate multiple XPs. |

XPs and XMPs Defined at the Research Forum, then Further Refined

- Research Forum was held at PPPL Feb. 24th-27th
 - 127 billion (??) proposals presented in Topical Science Group and Science Group breakout sessions.
 - Initial prioritizations performed.
 - Initial XP sequencing defined.
- Now in the process of reviewing and finalizing XPs and XMPs.
 - ? XMPs have been approved, ?? more in active development.
 - ?? XPs have been approved.
 - These are sufficient for the first ~2 months of the run campaign

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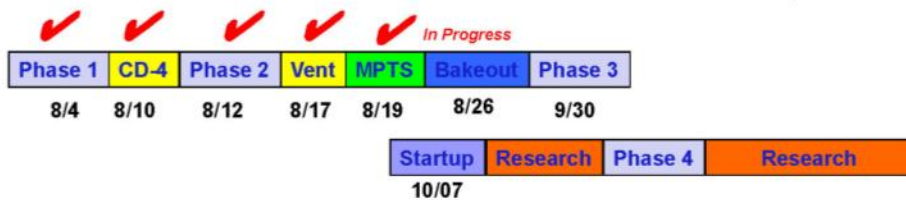
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Sequence From CD-4 To Full Research is Well Defined

- | | |
|---|---|
| <ul style="list-style-type: none"> • Phase 1 Coil Testing ✓ <ul style="list-style-type: none"> – Commission TF, OH, PF coil systems required for CD-4. • CD-4 ✓ • Phase 2 Coil Testing: ✓ <ul style="list-style-type: none"> – Do remaining coils for magnetics calibrations • Small Vent ✓ • MPTS Rayleigh-Raman ✓ • Bakeout ✓ | <ul style="list-style-type: none"> • Phase 3 Coil Testing <ul style="list-style-type: none"> – Prepare for Commissioning/Startup Phase • Commissioning/Startup Phase • Research Ops • Phase 4 Coil Testing <ul style="list-style-type: none"> – Increase to full fields for research phase • Final Research Operations |
|---|---|



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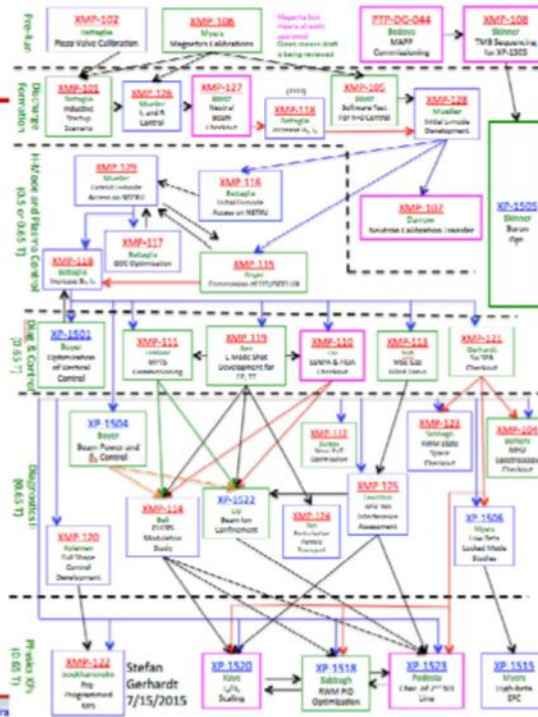
The NSTX-U Research Program Will Initiated By a Sequence of XMPs

- XMPs for pre-plasma calibrations (3)
- XMPs to reestablish basic “L-mode” plasma operations (7).
- XMPs for “H-mode” access and advanced plasma boundary control (5)
- XMPs for additional control development and initial diagnostic checkout (6)
- XMPs for advanced diagnostic checkout (6)

At the completion of this list, we will be ready to execute the critical XPs (I_p & B_T Scaling, Characterization of the 2nd NB Line)

The Linkages of the First XMPs and XPs Have Been Defined

- Obviously, not going to discuss this in detail.
- Engineering requirements are consistent with present facility plans.
 - 2 beam boxes
 - Full set of TF, OH, PF coils
 - TF to 0.65 T.
 - 6 SPAs (for RWM coils)
 - Boronization



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Physics Operations Staff+Collaborators Will Be Ready to Execute the NSTX-U Research Program

- Three NSTX physics operators will return to NSTX-U.
 - D. Mueller is a world-recognized tokamak driver.
 - Operated TFTR
 - Has collaborated on EAST and K-STAR control development over the last year.
 - D. Battaglia has spent the last 2 years as a DIII-D operator
 - Was responsible for the CD-4 XMPs
 - R. Raman (U. of Washington) provides leadership in CHI, MGI areas + physics operations.
- D. Mueller holding a physics operator course.
 - ½ in July, ½ in September.
 - Plan to train an additional 2-3 physics operators.
 - Slides for course:
 - http://nstx.pppl.gov/DragNDrop/Operations/Physics_Operations_Course/
- Major diagnostics have primary and backup support.

Summary: NSTX-U is Well on the Way To an Exciting First Run Campaign

- Upgrade was designed to facilitate the research program.
 - And successfully built (Ron's talk).
- The CD-4 plasma activity was very successful.
- The scientific program and management team are in place to develop and exploit the facility.
- The sequence of events leading to research operations is well defined, and we are well along the way.