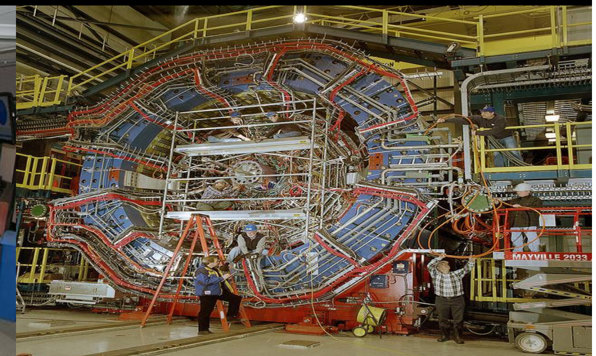
AUTOMATION EXPERIENCE AT THE RELATIVISTIC HEAVY ION COLLIDER







Christopher Zimmer
Brookhaven National Laboratory, Upton, NY USA

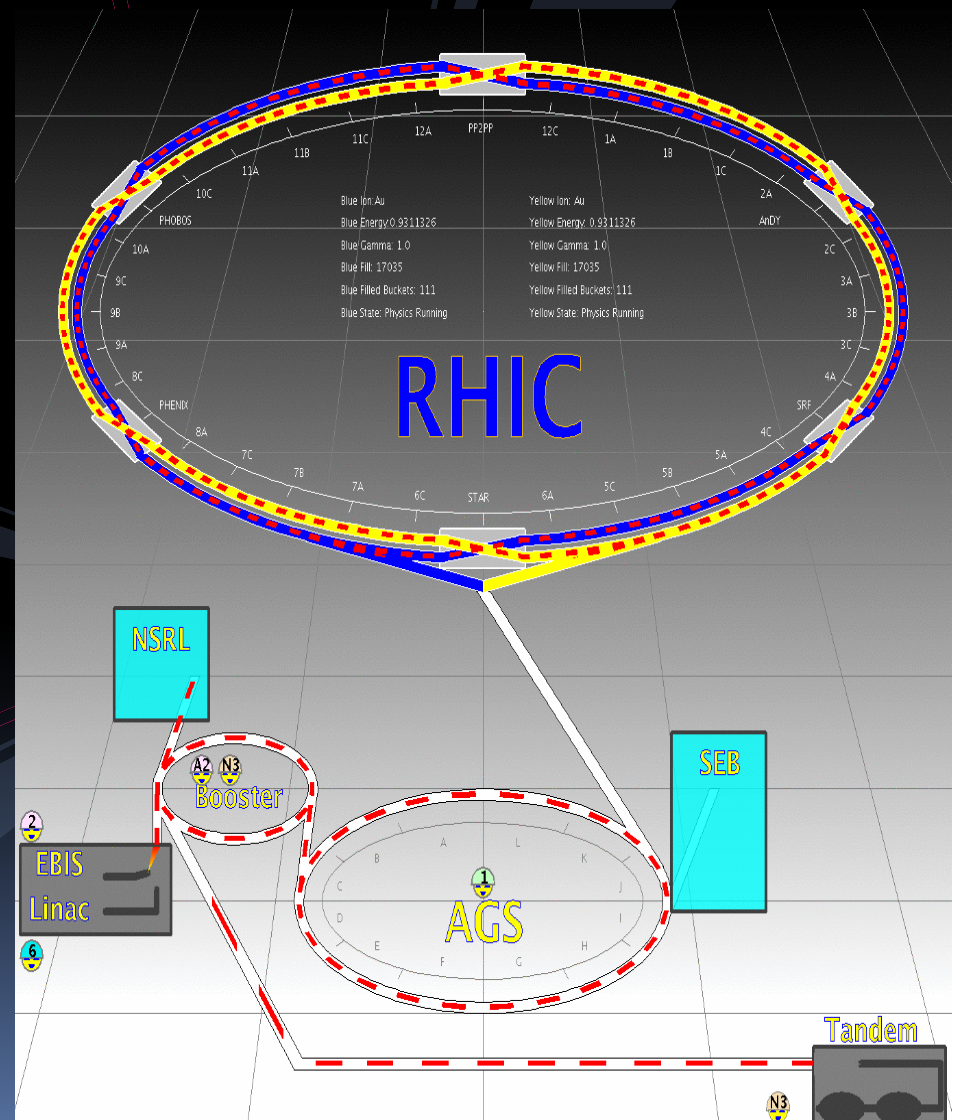
BROOKHAVEN NATIONAL LABORATORY

Workshop on Accelerator Operations
August 6-10, 2012

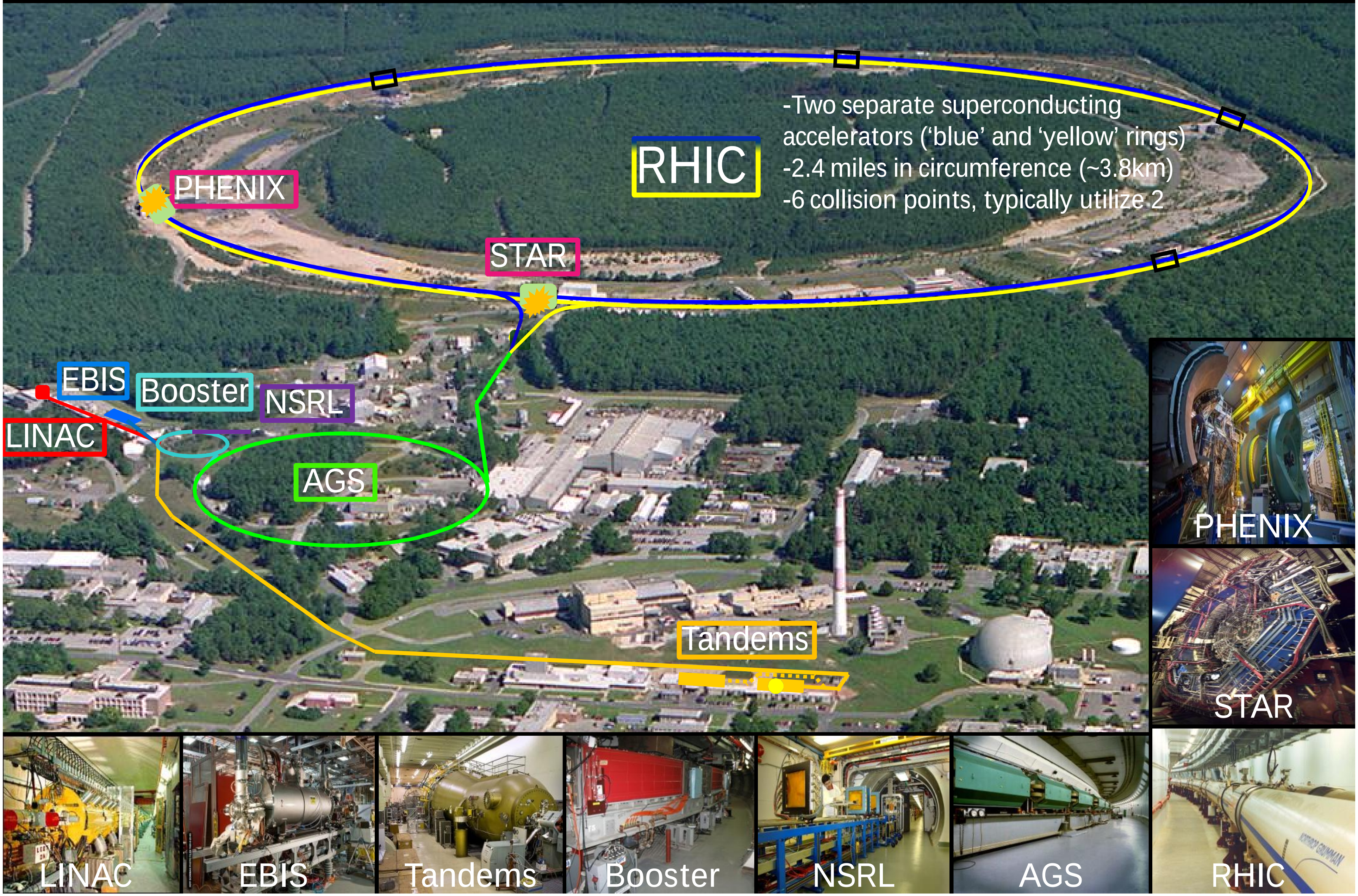
Office of Science
U.S. DEPARTMENT OF ENERGY

Outline

- -Overview of the RHIC complex
- -Examples of automation types
- -Need for automation
- -Reasons why our methods of automation have been successful
- -Perils of having many automated systems
- -Automation's effect on the skills of operators
- -Training and skill retention
- -Summary

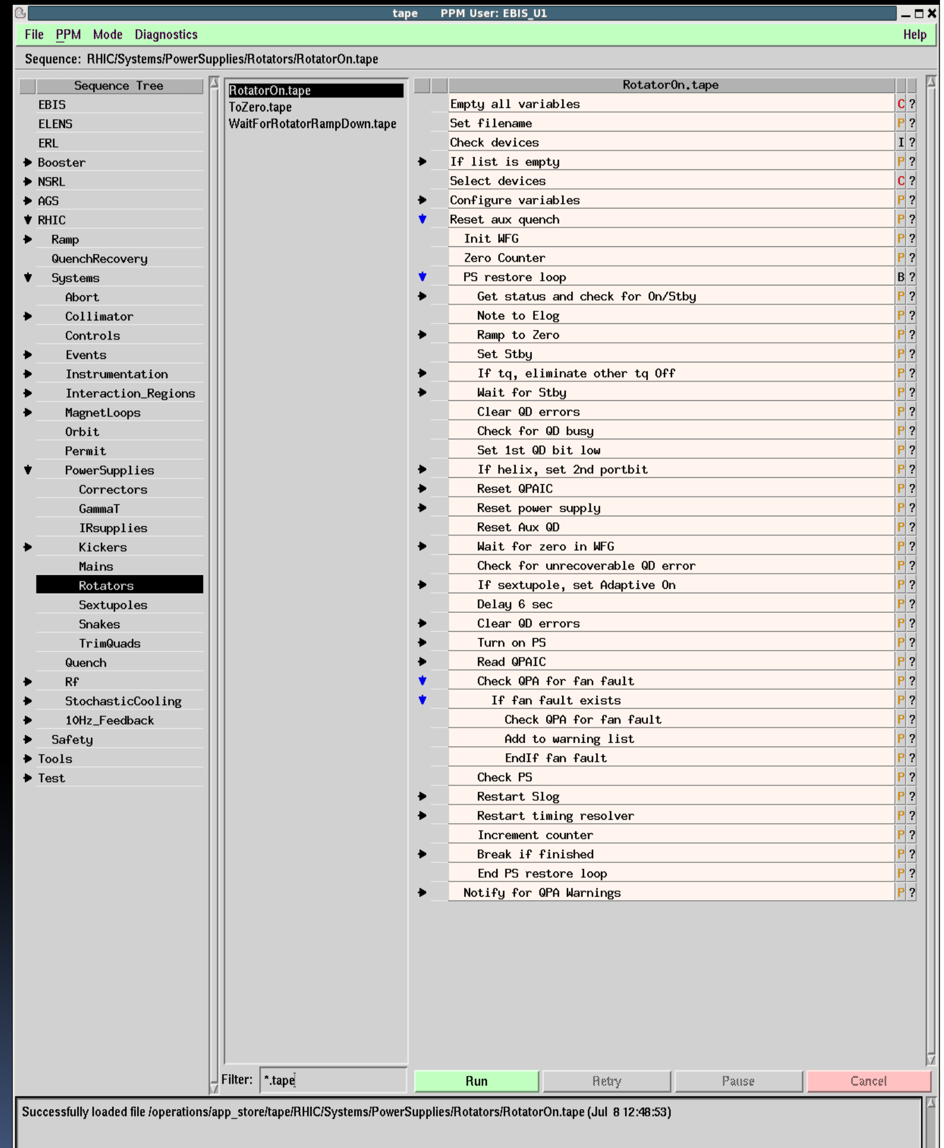


Overview of the RHIC Complex



Sequenced Automation Using TAPE

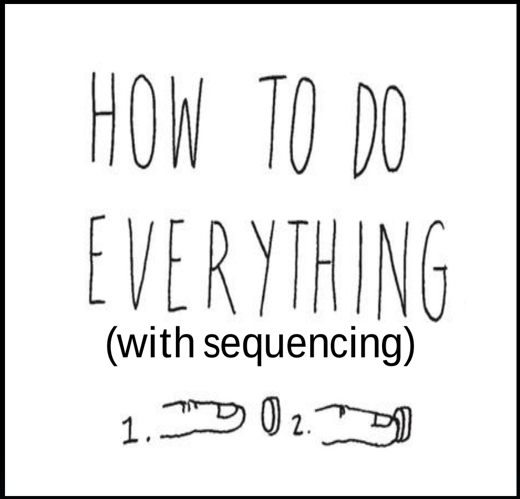
- TAPE program is extremely versatile and widely used in the operation of our accelerators
  - Generic automation tool
    - Sequencing using a graphical editor
  - Able to interact with controls devices, servers, applications and electronic log books
  - Incorporates many traditional programming tools (variables, conditional statements, loops, etc.)
- Although the application is in essence simplistic, it is a highly effective/flexible tool



TAPE (Tool for Automated Procedure Execution)

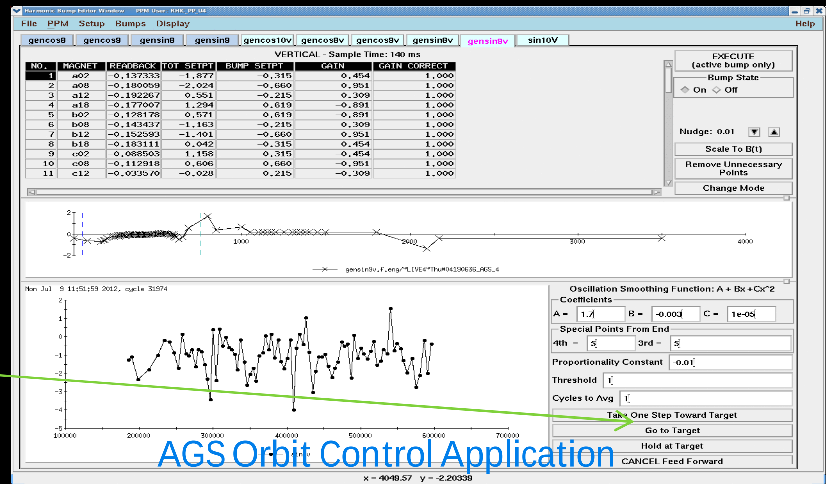
Some Examples of TAPE Sequencer Usage

- Preparation of RHIC for ramping (instrumentation, RF, power supplies, triggers, etc.)
- Ramping RHIC to full energy
  - Also putting the beams into collision
- Turning on/off hundreds of power supplies (access/power dip/quench)
- ‘Mode switching’
  - Changing species in the injectors
- NSRL energy changes
- Documentation of running conditions
- General management over a large variety of systems



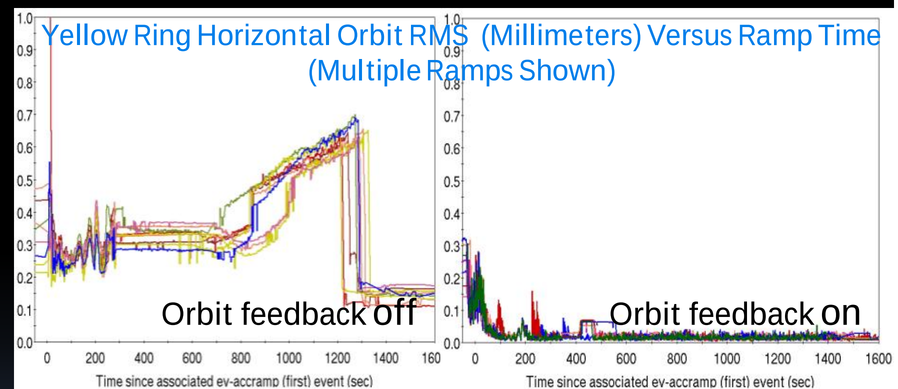
Hard-coded Beam-based Correction Schemes

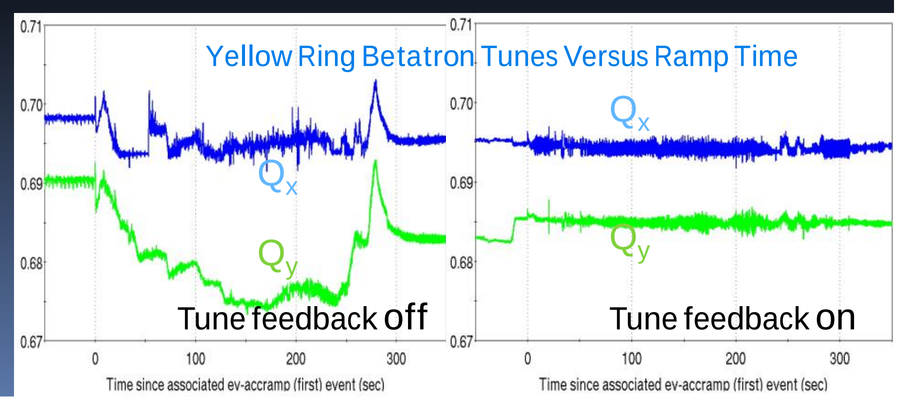
- Automatic orbit correction in AGS
  - Acquires an orbit and calculates the necessary correction
  - User applies correction by simply pushing a button



AGS Orbit Control Application

- Orbit and tune feedback in RHIC
  - Continuous feedback loops that maintain the orbit/tunes at ideal values over the ramp duration
  - Feedbacks can run at injection (before filling RHIC) to quickly optimize beam lifetime





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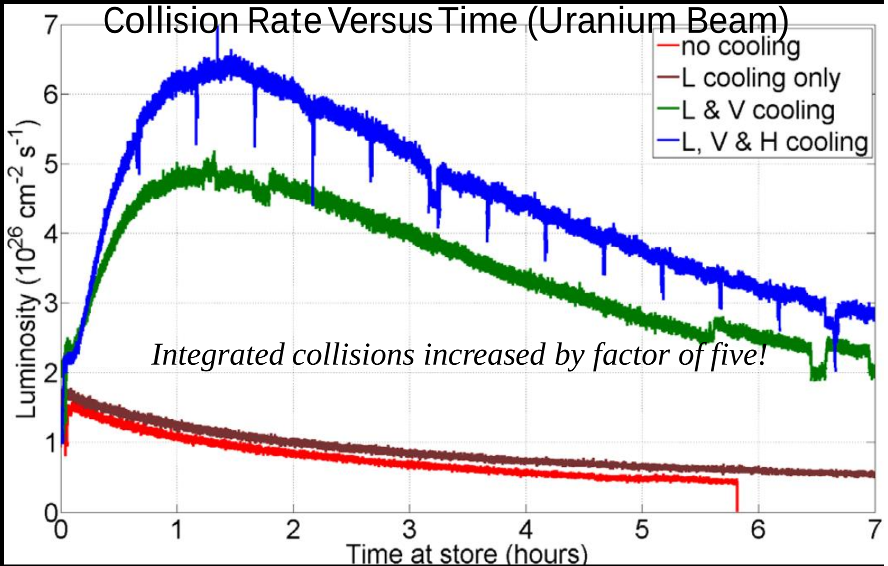
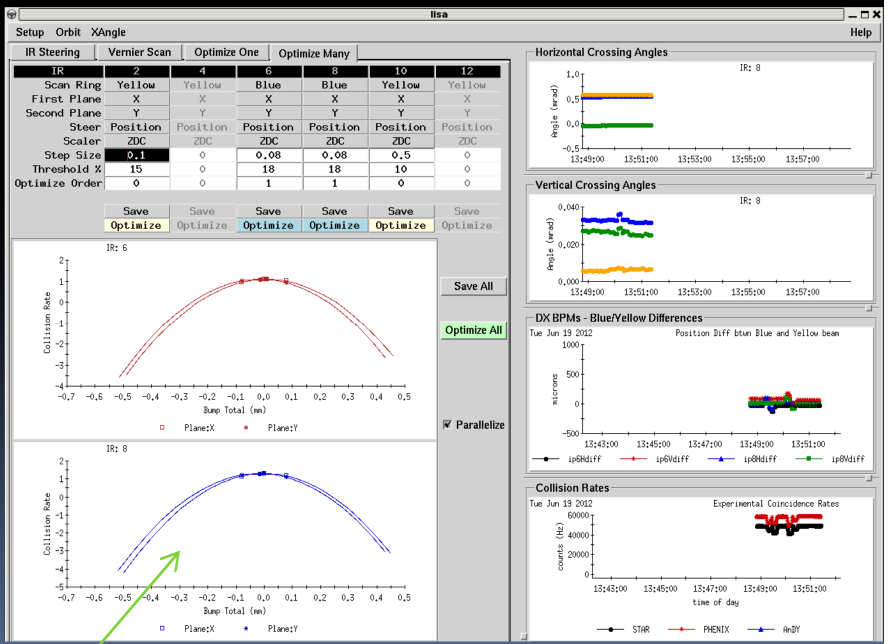
Other Code-driven Beam-based Corrections

- Stochastic cooling in RHIC
  - Decreases the beam emittance in all three planes (H, V, L)
    - Uses a sophisticated pickup/kicker arrangement to measure and mitigate the diffusion of particles
  - Increases collisions by factor 2-5
- Automated optimization of collision steering in RHIC
  - Implements minor steering adjustments using the collision rate as a figure of merit
  - Steers multiple interaction regions in parallel
  - Especially important with the advent of stochastic cooling

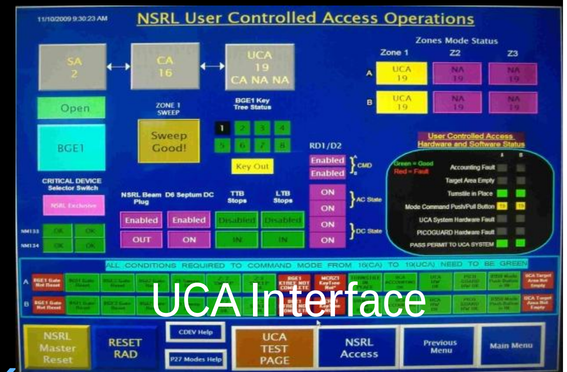




lisa (Luminosity and IR Steering Application)

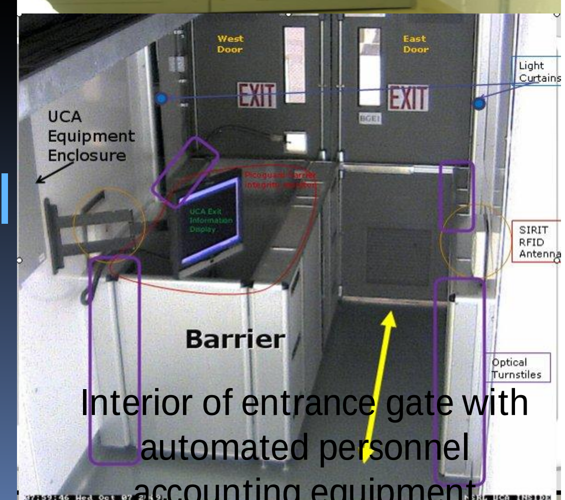
User Controlled Access at NSRL

- Fully automated access system
  - Controls entry/exit from the target exposure room
    - MCR operators used to perform this task
  - When an entrance is requested, system places area into a controlled access state and prevents the delivery of beam
  - User obtains an RFID key from iris scanner
  - System accounts for entry/exit of each person using an arrangement of optical turnstiles and RFID antennas
  - Restores the beam after access



UCA Interface


Outside entrance gate to target exposure area



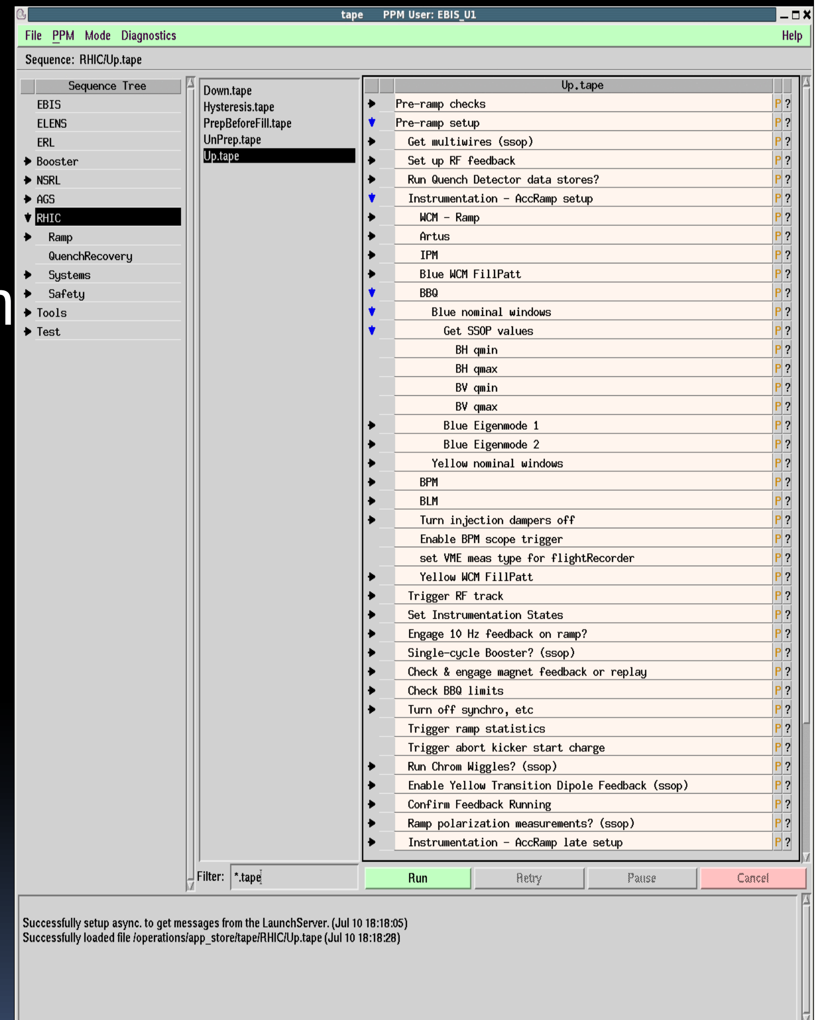
Interior of entrance gate with automated personnel accounting equipment

Automation is Necessary!

- Preparing for and executing a RHIC ramp necessitates hundreds of verifications/initializations/triggers
  - Impractical and susceptible to human error
- Mode switching sequence provides quick (~2 minutes!) and reliable reconfiguration of the injector chain for running different species
- NSRL has a need for rapid and consistent energy changes
- Controlling hundreds of power supplies easily managed with TAPE
- Orbit/tune feedback has a profound effect on RHIC setup time
  - Only takes 1-2 test ramps to reach full energy with a new species
  - Enables running of several species, increases time in collision
- Stochastic cooling provides an incredible benefit, but is complex
- User Controlled Access for NSRL has been a huge success, and has freed operators from performing a very menial and repetitive task

Our Sequenced Automation Method Works Well

- The simplicity of our sequencing application is a key to its success
- The barrier for understanding, creating and modifying automation schemes using TAPE is low
  - Steps are clearly laid out
  - Anyone can understand the steps
  - Proficiency in code-writing not required to create or modify scripts
- Almost any repetitive task can be automated using TAPE



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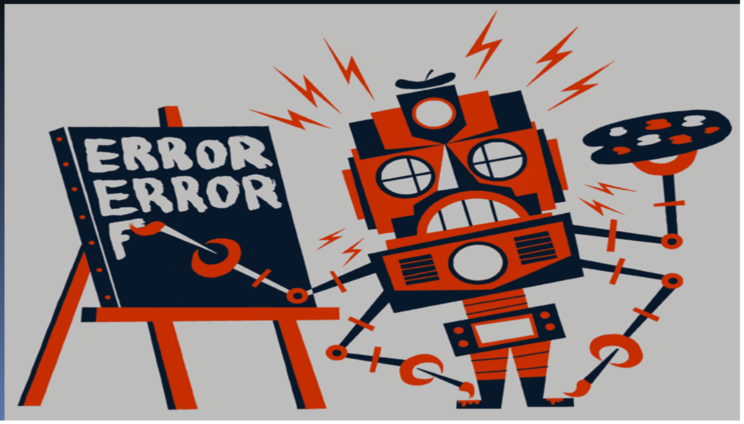
Issues With Sequenced Automation

- Steps can and do fail. The error messages given by the application are at times arcane
  - Error messages could be more informative
- If the application freezes/crashes, there can be confusion as to what steps were executed
  - Every step is logged which aids in diagnosis, but the abnormal machine state can be tricky
- Ease of running a sequence (single button click) can lead to inadvertently running the wrong sequence
  - Operators must exercise caution



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Issues With Other Automation Types

- RHIC beam-based feedback systems were implemented by a single person, and are only understood by that person
  - Single point of failure
  - We rely on these systems heavily, they have become essential
- Stochastic cooling is another black box
  - Very few people understand how the system works
  - It also occasionally gets into a bad state, increases emittance
- User Controlled Access at NSRL
  - Susceptible to hardware faults, coding errors and loose wires
    - Multiple issues when system first brought online, better now
    - Necessary byproducts of commissioning

Does Automation Hurt the Operators?

- The consensus among our group is that automation, when properly executed, does not by virtue significantly deteriorate operational skills
  - Automation undoubtedly gives the operators less tasks to execute, but…
    - Many automated tasks are monotonous and require little skill
      - Automating tedious tasks improves quality of life for operators

Does Automation Hurt Operators (2)?

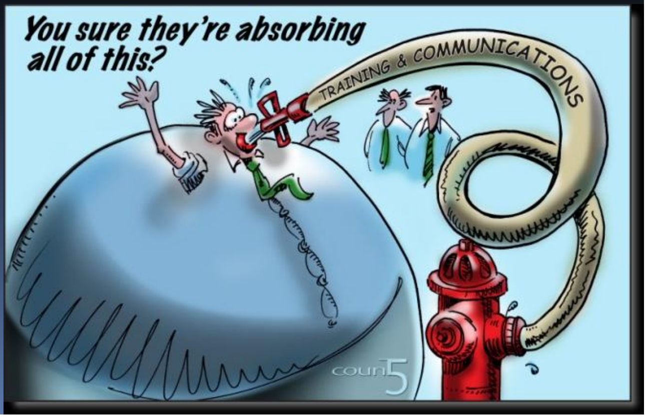
- Our sequencing utility improves operator creativity/skills
  - Encourages improvement of automation schemes
  - Application is a window to the controls system
- Large majority of tuning and troubleshooting still done by hand
- Proficient operators will usually understand what automation of skilled tasks accomplishes and can execute those tasks
  - Assuming that the automation is transparent

Necessary Supplements to Automation

- Automation certainly fosters an environment where it *can* be more difficult to obtain/retain certain skills
  - As automation encroaches more upon skilled (typically human-driven) accelerator troubleshooting and tuning activities, the negative effects will become more pronounced
    - Accelerators that tune and fix themselves?
- Negative effects on operator competency seem to correlate with an opaque automation scheme and/or a lack of accompanying education/training
- Automation must be supplemented with regimented training and hands on experience

Imparting and Retaining Skills

- We administer lecture-styled training on a variety of topics
- Our group also requires the passing of ‘practical exams’
  - Hands on test of troubleshooting ability
  - Sr. operator ‘breaks’ machine(s), jr. operator fixes problems with machine(s)
  - Some practicals involve demonstrating competency in an automated task
    - NSRL energy change



Skill Retention With Automation

- We could do better to ensure understanding of automated tasks
  - Limited number of practical exams
    - No mode switching practical, no recertification exams
  - Formal training courses are lacking; we rely more on informal training while on shift
  - “Push the magic button and call me if it fails” needs to be avoided
    - Instead of fielding calls when system breaks, teach operators about system

Summary

- Any task that can be reliably automated should be
  - Leads to more efficient operation and reduces human error
  - We have yet to see a glaring example of too much automation
  - Automation works quite well for us, with a few caveats
- Automation needs to be as transparent as possible
  - Not every automation scheme can be perfectly transparent
  - Better dissemination of information in those cases
- Use of automation should ideally be accompanied (even preceded) by a demonstration that the user understands the fundamentals of the task and is able to execute the task
  - Don’t give a child a calculator to divide numbers without first teaching them long division; they need to be able to divide by hand if the calculator breaks!
- A solid foundation of training along with continuing education is a necessary supplement to automation
  - Operators and support personnel can proactively minimize the possible negative effects of automation