# A Fast Talk On Slow Locks

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AI IN THE ACCELERATOR

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# Overview

The slow orbit locks can be a source of instability in transport and on target

- Transport problems
  - Induced oscillations, misbehaving locks, beam scraping
- Improve stability of the beam orbit and position on target
  - Time lost may be smaller, but helps overall “stability budget”

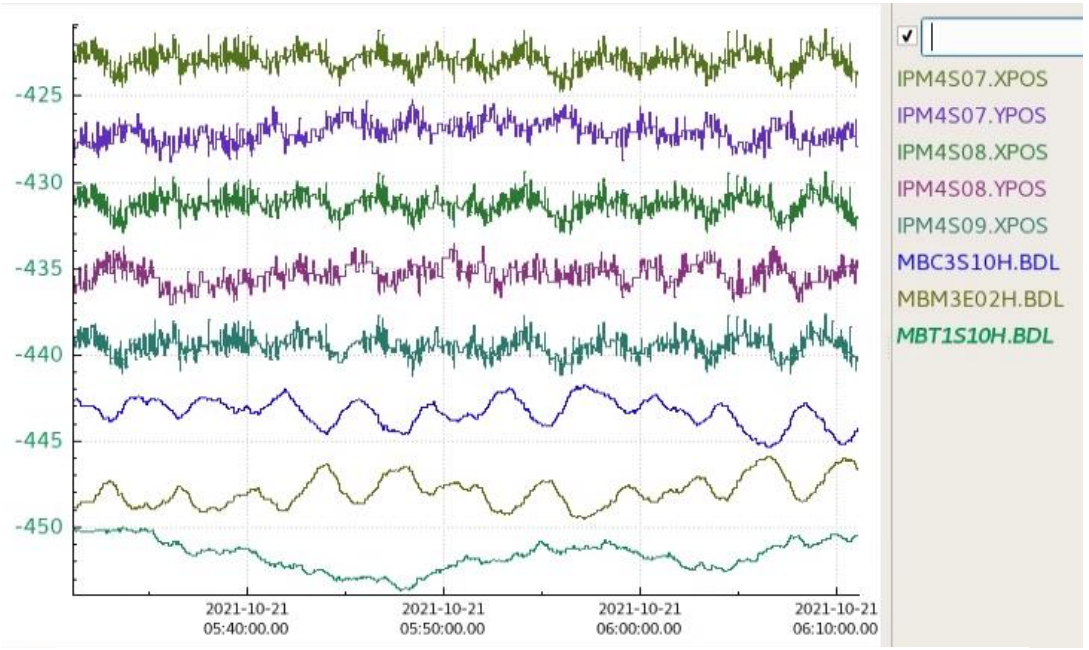
Orbit lock system could use and yield improved alarms

- Orbit fluctuations could alert of coming problems
- FY20 Q4: Unnoticed degraded control of a corrector. 10 events, 7.3 hours lost

Impacts operations and experimenters

SBIR/STTR under review

We have years of orbit lock data on hand




**Orbit Oscillations Investigation....**

**Lognumber 3929564. Submitted by deir on Thu, 10/21/2021 - 08:19.**

Last updated on Thu, 10/21/2021 - 08:20

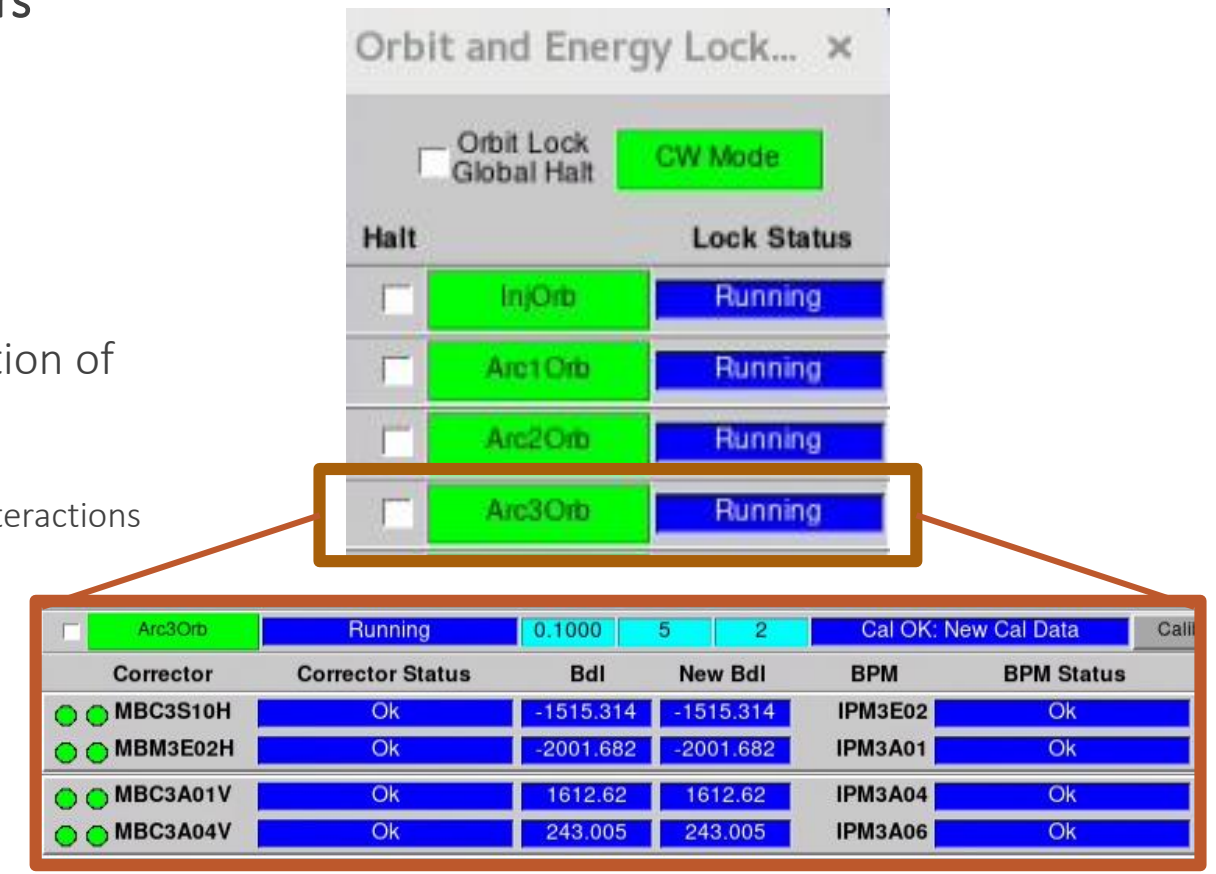
# Existing Slow Orbit Lock System

A group of ~25 independent feedback controllers positioned along beam path

- Each lock is a set of BPMs and corrector magnets
- Updates based on a fitted response matrix
- Upstream changes impact down stream locks
- Locks aren't aware of each other
- Locks update every five second and only use portion of estimated correction
  - Neither sequentially nor in unison
  - Changes slow enough and small enough that un-modeled interactions can settle out

Software was written 10+ years ago

- Relies on older in-house software (CDEV)
- Refresh needed



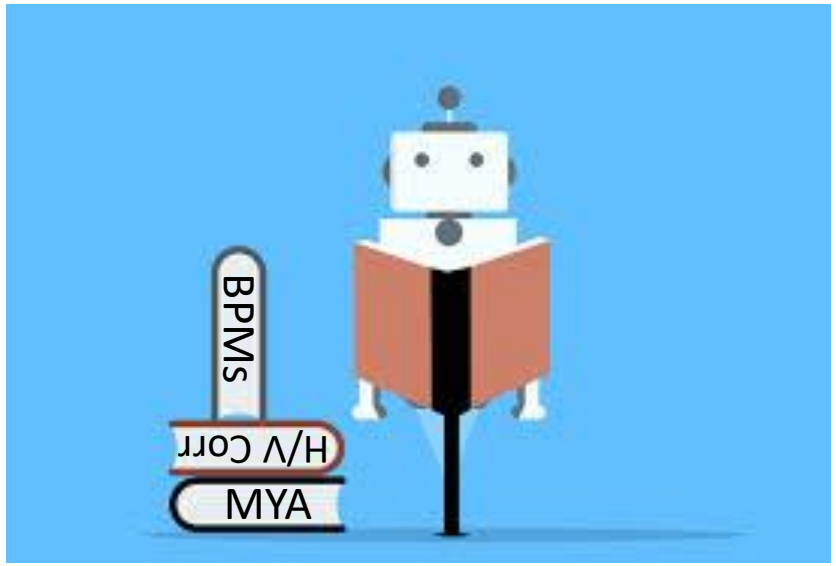
# A Better Mousetrap?

Global lock system reduces in fighting of locks and allows for faster update rate

Surrogate model and AI Controller Approach

- Surrogate model using magnet and BPM MYA data
  - Works beyond first order effects
  - Could include additional inputs
    - Non-lock magnets/BPMs
    - Linac energy gain fluctuations
    - Tunnel temperatures (expansion)
- AI controller
  - Reinforcement learning agent?
  - Neural network?
  - Other techniques?

Online learning to keep model “fresh”




Lots of other approaches exist

- Extending current approach to global response matrix?

# Good, Bad and Ugly

Potential upsides

- Make beam more stable
- Reduce beam scraping due to oscillations
- Less time fixing/investigating problems with individual lock interactions
- Give us experience with machine learning control approaches

Potential drawbacks

- Might be hard/impossible to disable a single “lock”
- More complicated
- Requires ML controls staff on-hand to maintain long-term
- Model maintenance required

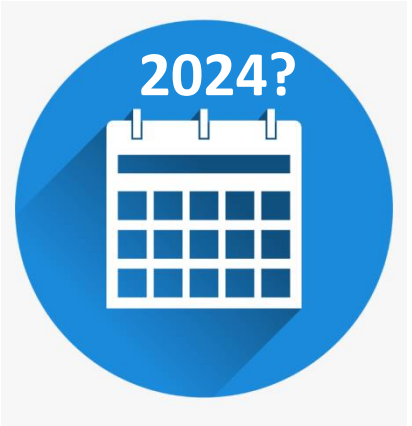
Risks

- We don’t like new approach after some time, but old tools have atrophied
- Difficult to maintain labor force
- Requires thought for lifecycle maintenance of new artifacts (model, controller, data)
- Who “owns” it?

# Good, Fast, and Cheap?

This could take awhile.  Difficult to say just how long.

- Build surrogate model, develop AI controller, develop software
- ~2 years not unreasonable to have a production system




Costs would be almost 100% labor-related

- Any new hardware needed?

How to measure success?

- How do we currently measure and track orbit lock performance?
- Improving those metrics?