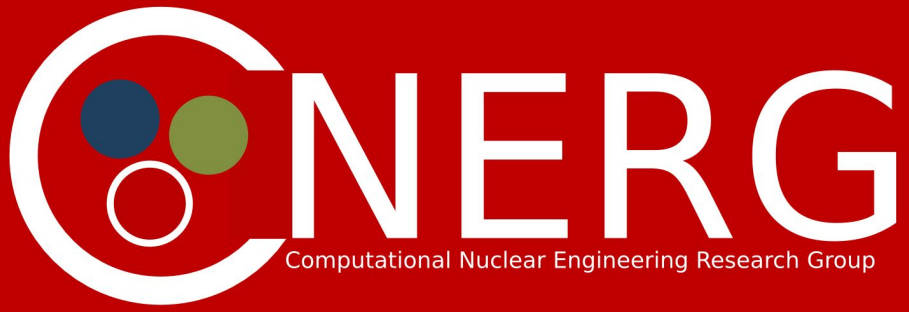
Modeling JCPOA Breakout Using Cyclus

Baptiste Mouginot, Kathryn Mummah,
Paul P.H. Wilson

TWoFCS3 - July 11, 2018



Overview

- JCPOA Details
- Enrichment Modeling
- Cascade Design
- Misuse Models
- HEU Production

JCPOA Enrichment Limitations

- IR-1 type centrifuges
- 5060 machines
- 3.67% enrichment

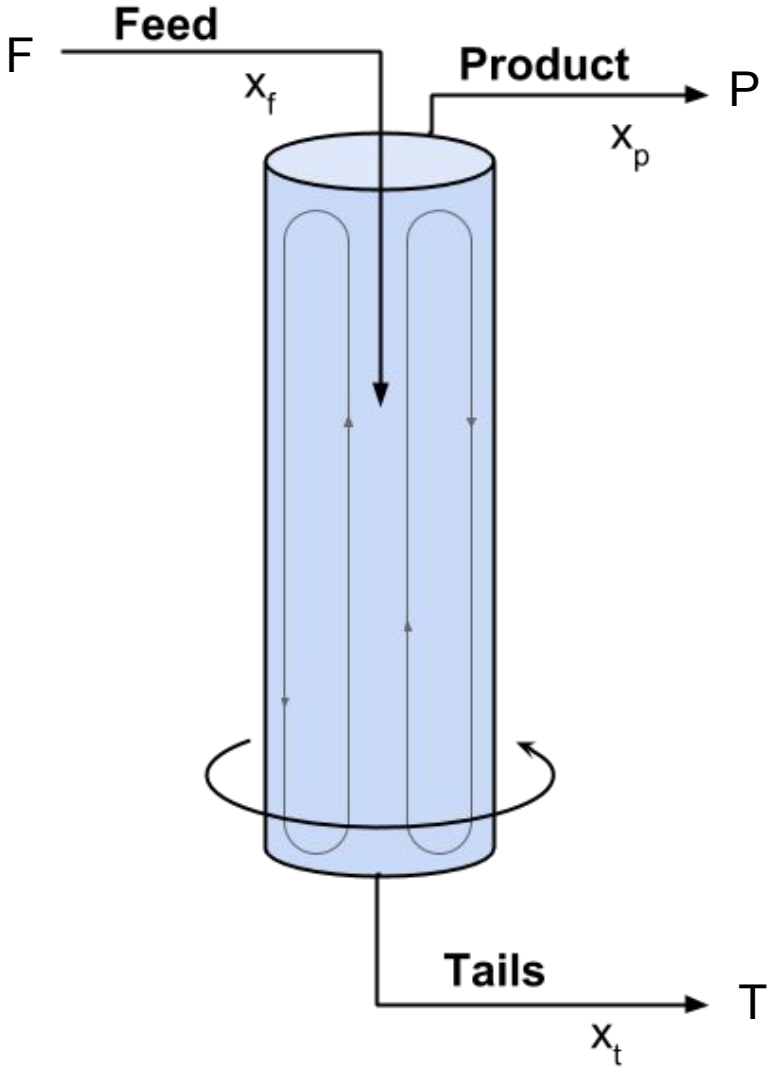
Goal of this Study

- Assume IR-1 machines are configured in cascades ideal for LEU production (3.67%)
- Determine HEU production rate if material is refed into cascades
  - Account for realistic cascade performance in non-ideal conditions
- Implement in fuel cycle simulator to facilitate future complex flows

Typical Enrichment Treatment

- Enrichment is upstream commodity
- Total SWU needs calculated from fuel quantity and enrichment
- Does not consider actual cascade performance

Single Centrifuge Model



$$\delta U_{Ratz}(L, F, \theta, Z_p)$$ [1]

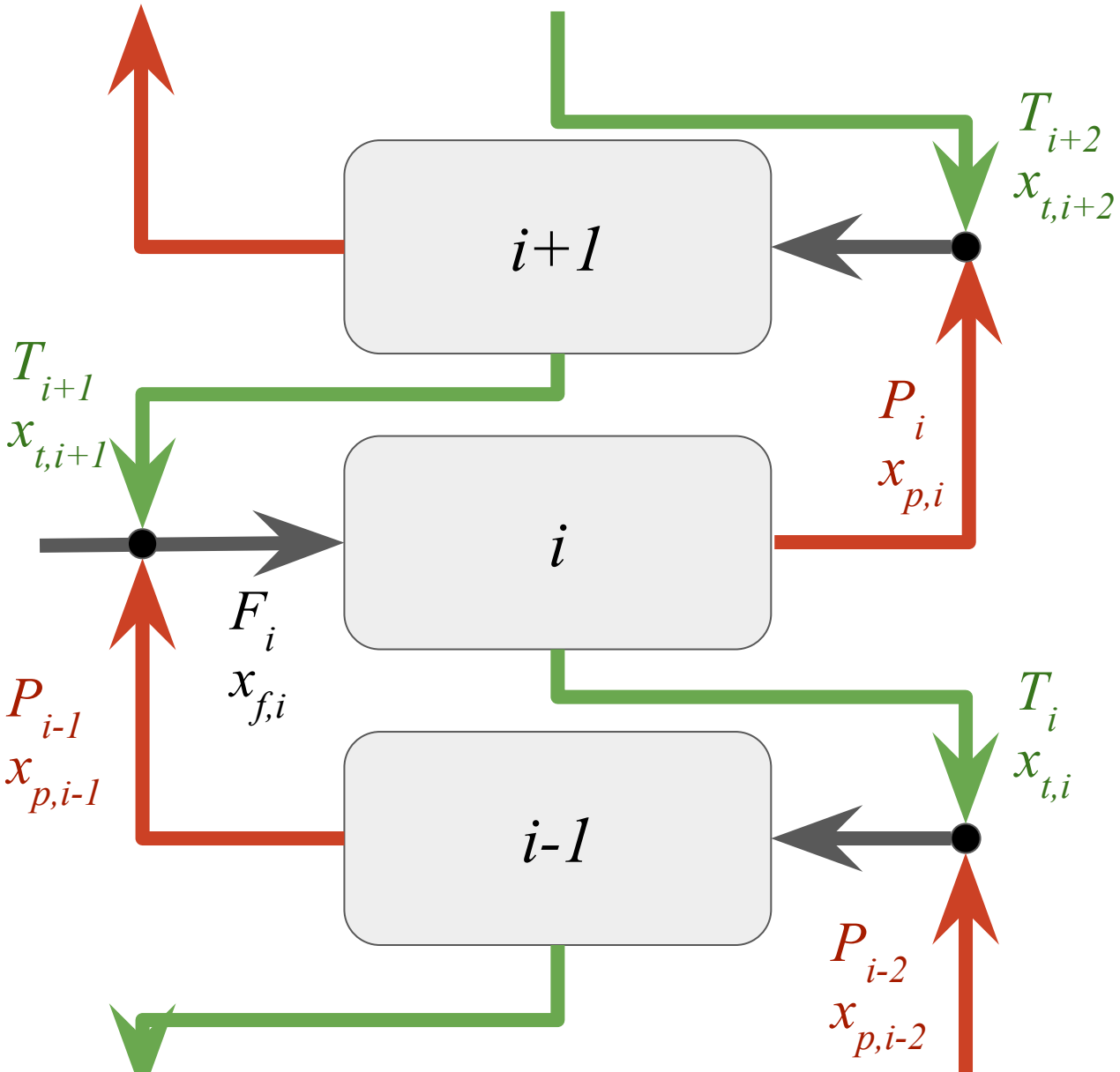
$$\alpha = \frac{x_p}{1-x_p}\frac{1-x_f}{x_f}$$

$$\beta = \frac{x_f}{1-x_f}\frac{1-x_t}{x_t}$$

$$\theta = \frac{P}{F}$$

$$\delta U = \frac{\theta}{1-\theta} F \frac{(\alpha-1)^2}{2}$$

Cascade Design



Ideal Cascade

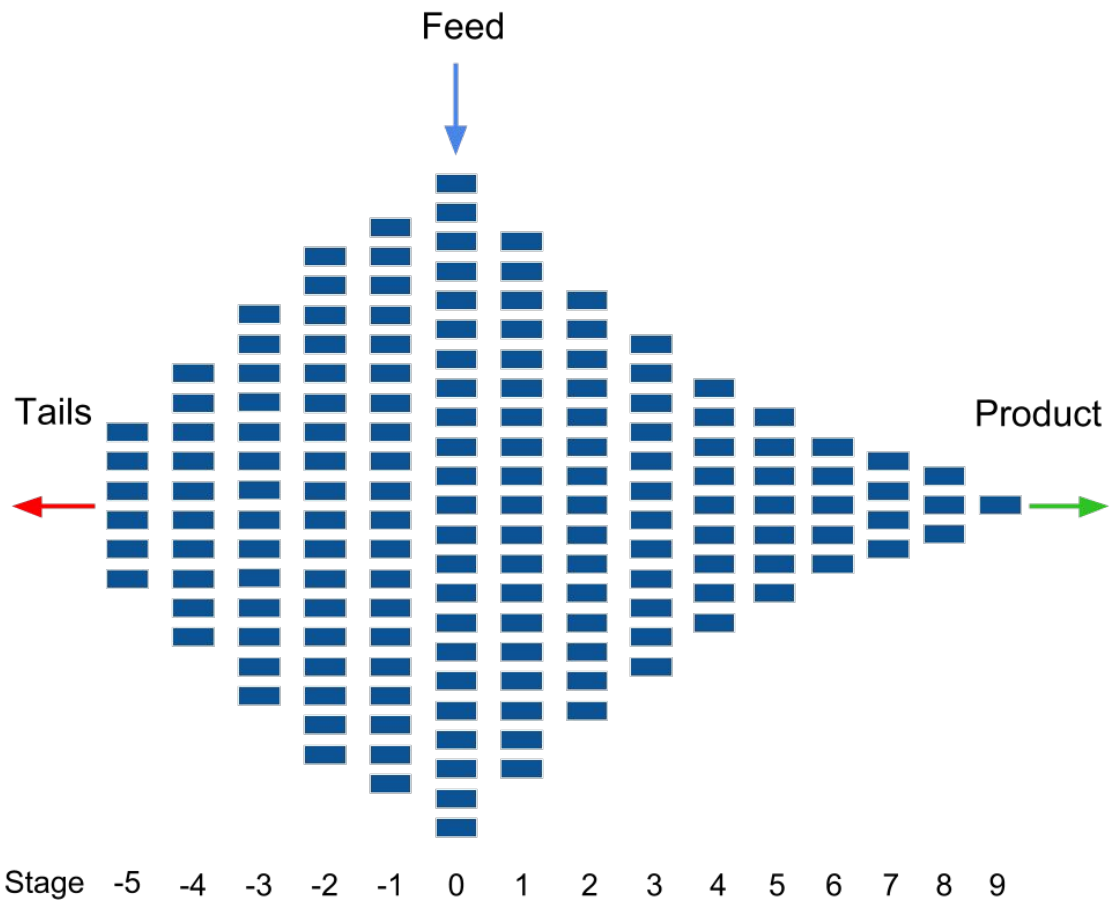
$$\alpha_i = \beta_i$$

$$x_{p,i-1} = x_{t,i+1}$$

$$\theta_i = f(\alpha, \beta, x_{f,i})$$

Solve for flows between stages

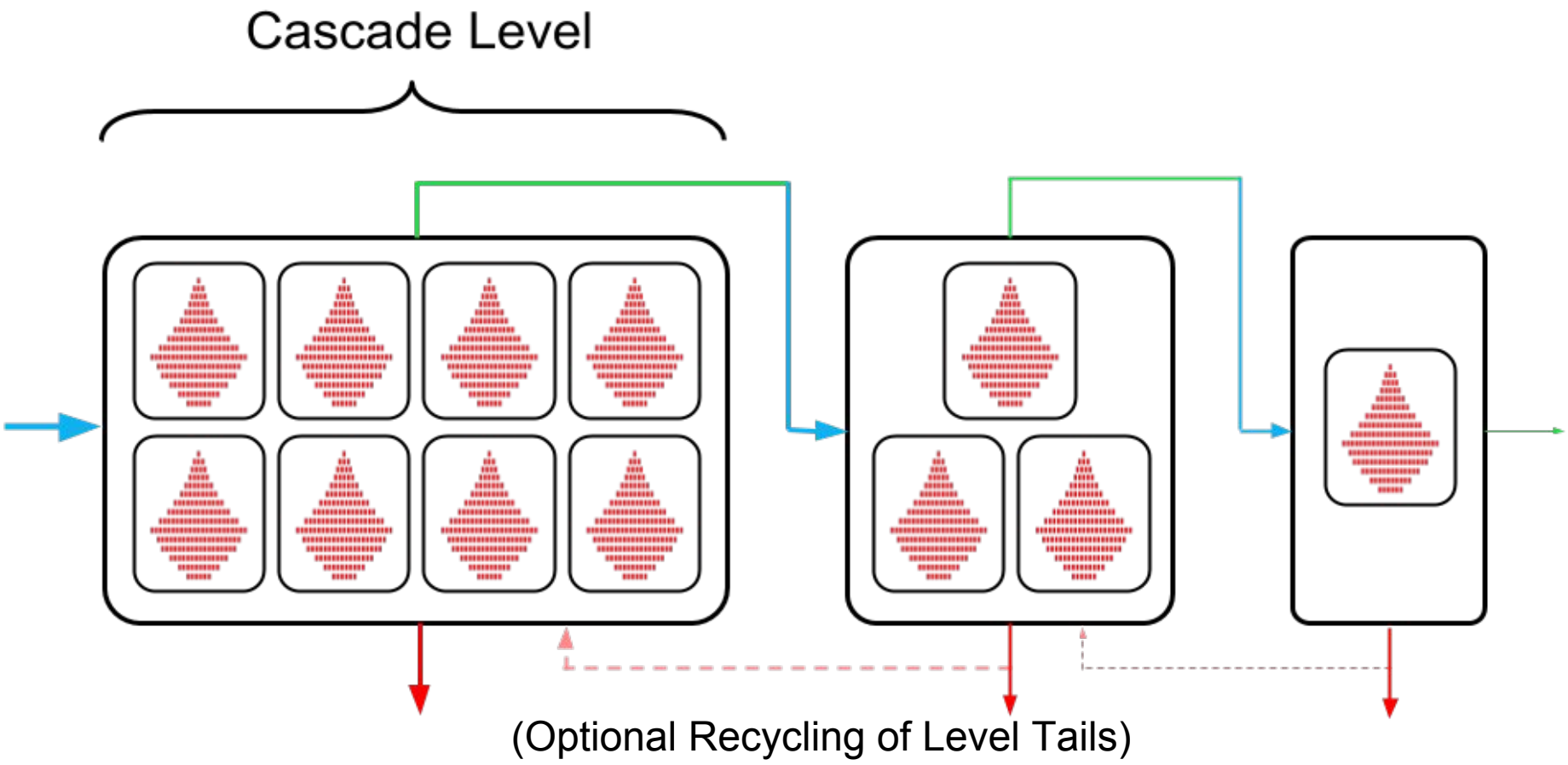
Cascade Design



Ideal Cascade

- 30 cascades
- 167 centrifuges per cascade
- 10 enriching stages
- 4 stripping stages

Cascade Misuse

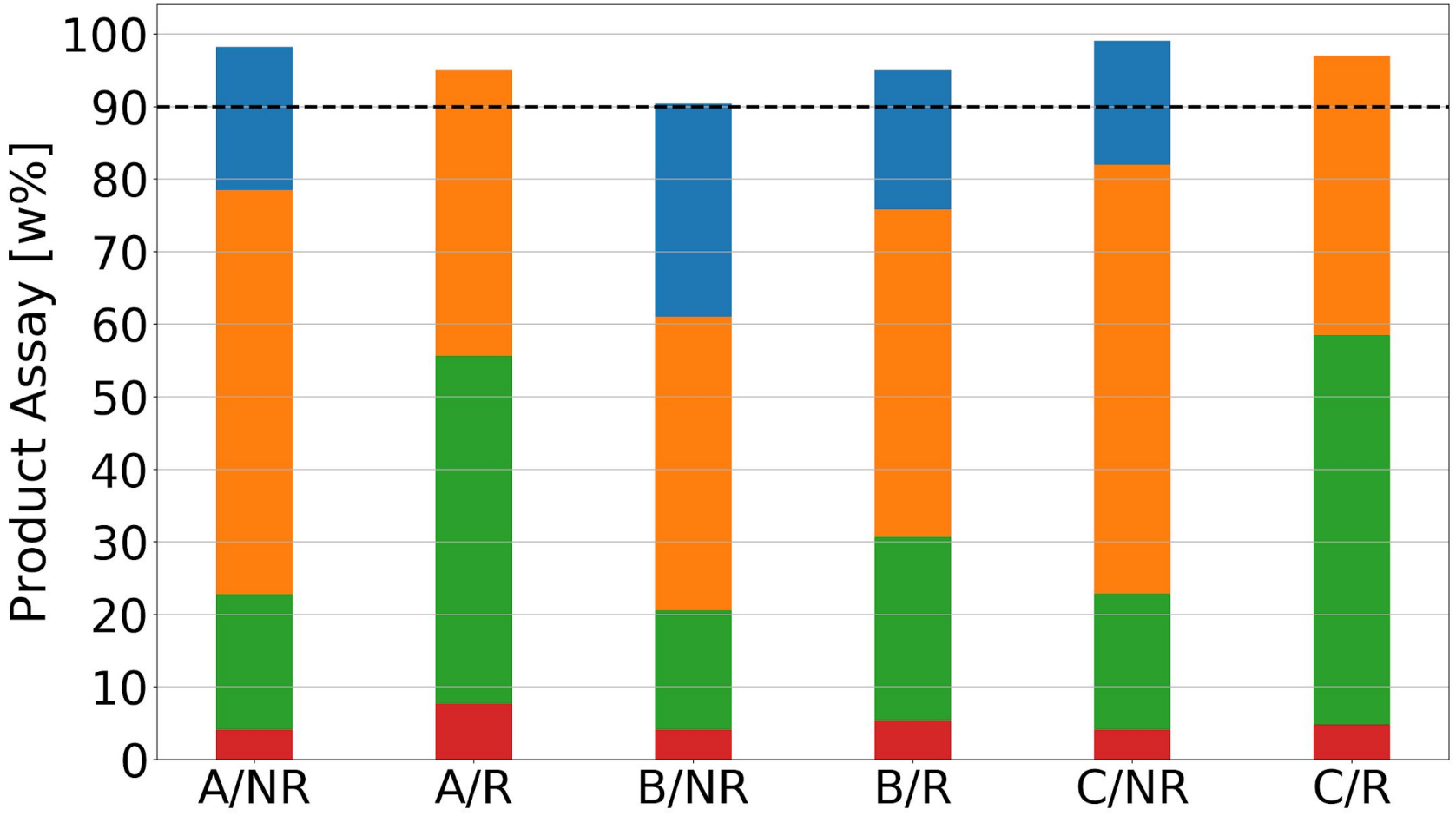


Impact on Centrifuge Machines

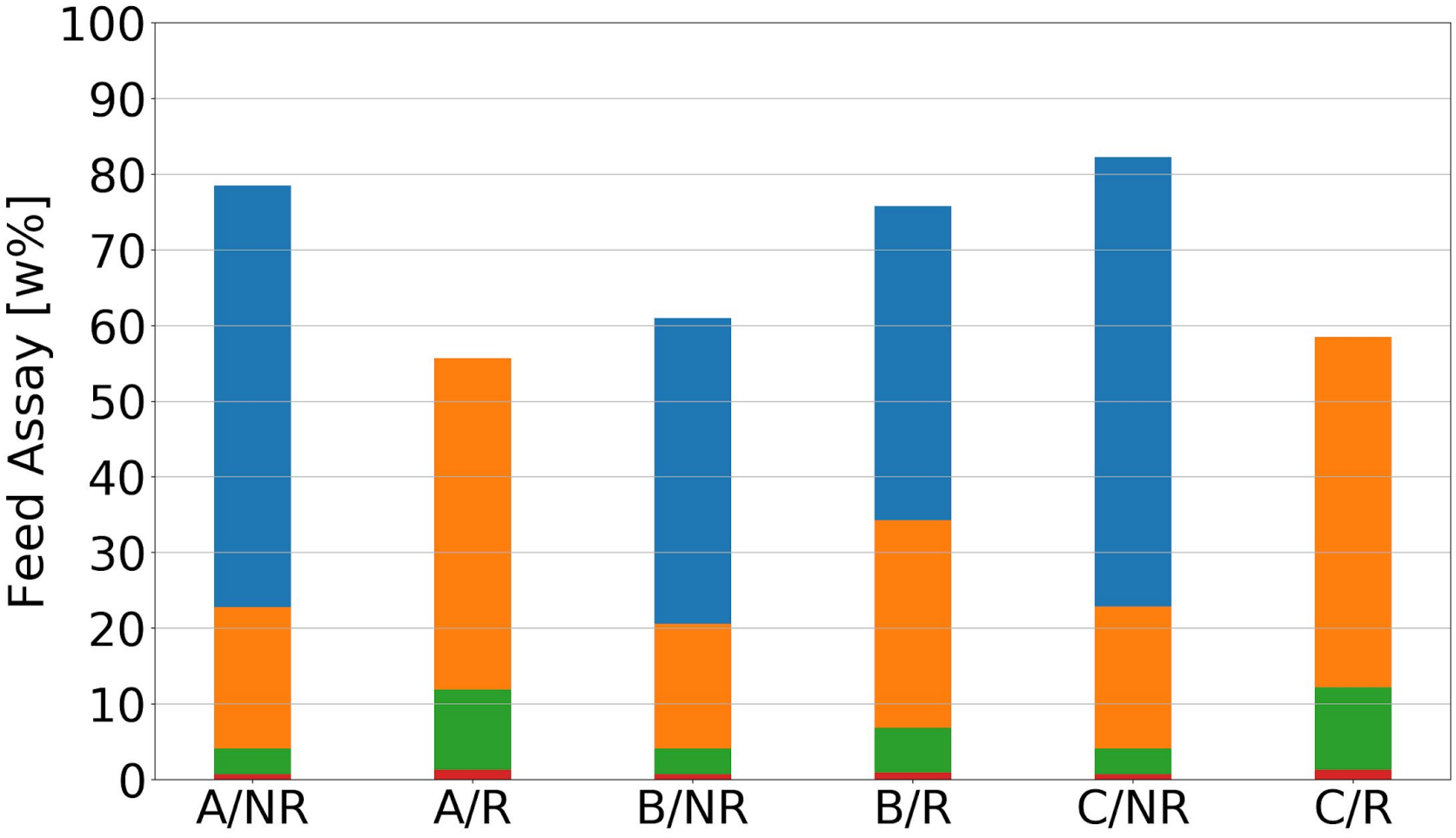
Three model choices

Model	**A**	**B**	**C**
Constant parameters	α_i, θ_i	$\alpha_i = \beta_i$	$\gamma_i = \alpha_i \cdot \beta_i, \theta_i$
Varying parameters	β_i	θ_i	α_i, β_i
Assay determination	blended	ideal	blended
Stage flows	unchanged	reduced	unchanged

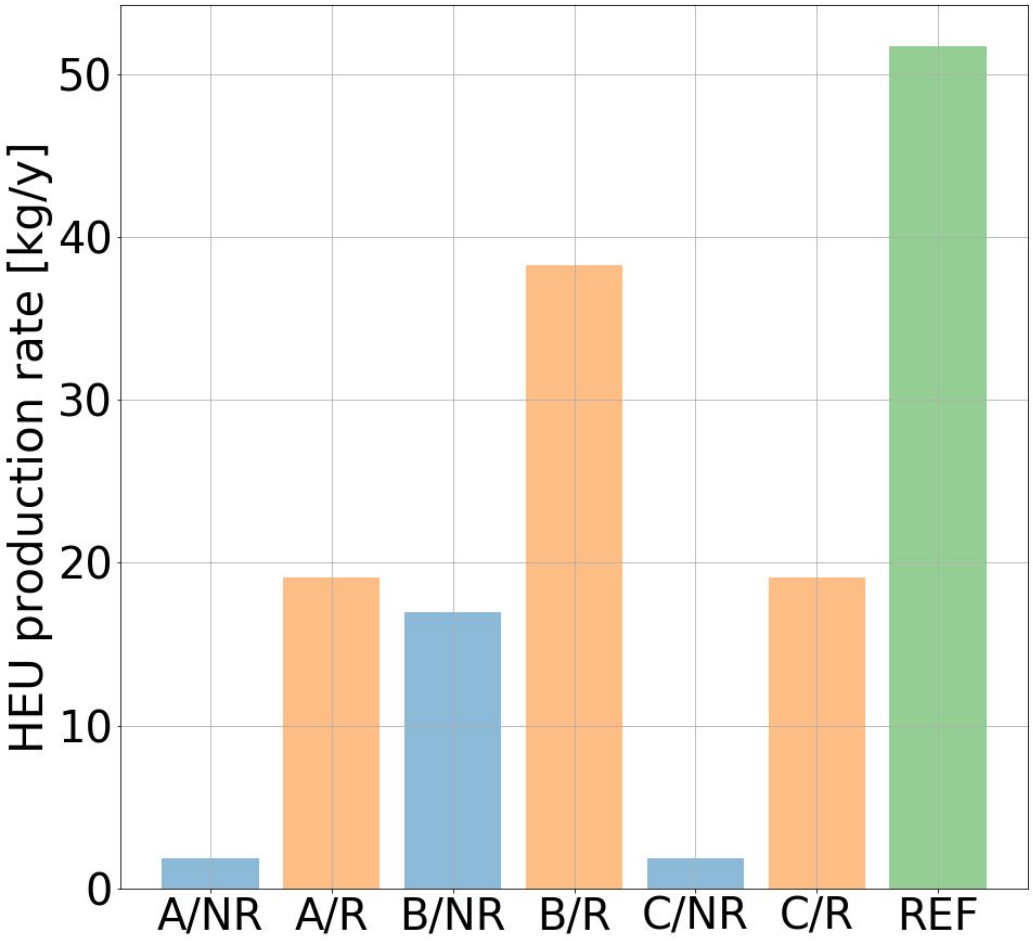
Product Assay by Level



Feed Assay by Level



HEU Production Rate



Limitations

- Assume fundamental centrifuge operation is not altered
- Potentially low flow rates in some cascades/centrifuges

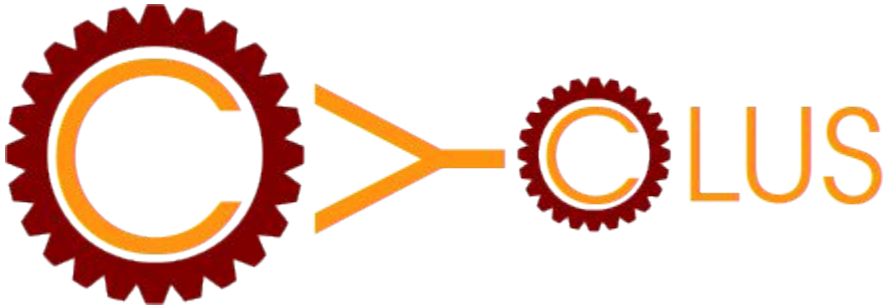
Conclusion

Refeeding enriched material into cascades ideal for LEU achieves HEU production rates that are 40-80% of cascades ideal for HEU

Significant quantity in ~8-15 months

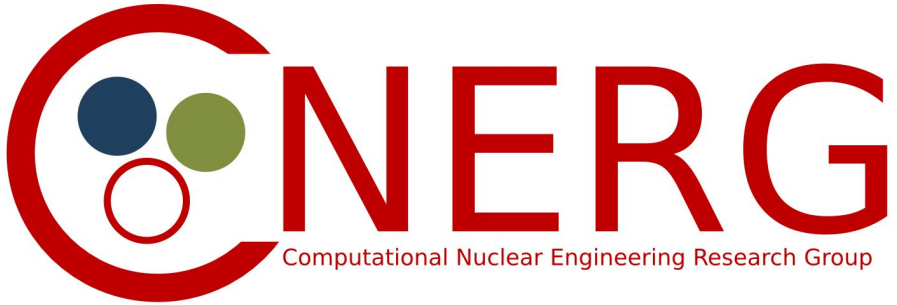
Acknowledgements

This work was supported, in part, by US Department of Energy's National Nuclear Security Administration through the Consortium for Verification Technology.



http://fuelcycle.org

Cascade Enrichment Cyclus Module
http://github.com/cnerg/mbmore



References

[1] E. RÄTZ, Analytische Lösungen für die Trennleistung von Gaszentrifugen zur Urananreicherung, PhD dissertation, Technical University of Berlin (21983).

Tails Assay by Level