Mixed-Criticality Job Models: A Comparison

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Mixed-Criticality Systems

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  Need significant resource over-provisioning to guarantee their temporal correctness, which leads to highly inefficient resource usage at run-time!

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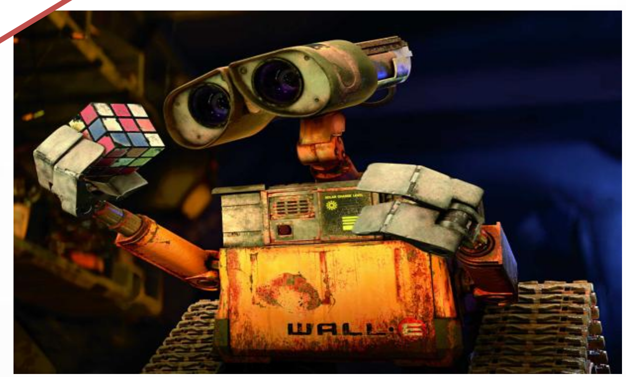
- Traditional non-MC design:
  Need significant resource over-provisioning to guarantee their temporal correctness, which leads to highly inefficient resource usage at run-time!
- MC:
  Over-provisioned resources (to more important tasks) can be used to execute less important ones.

SWaP!

Models

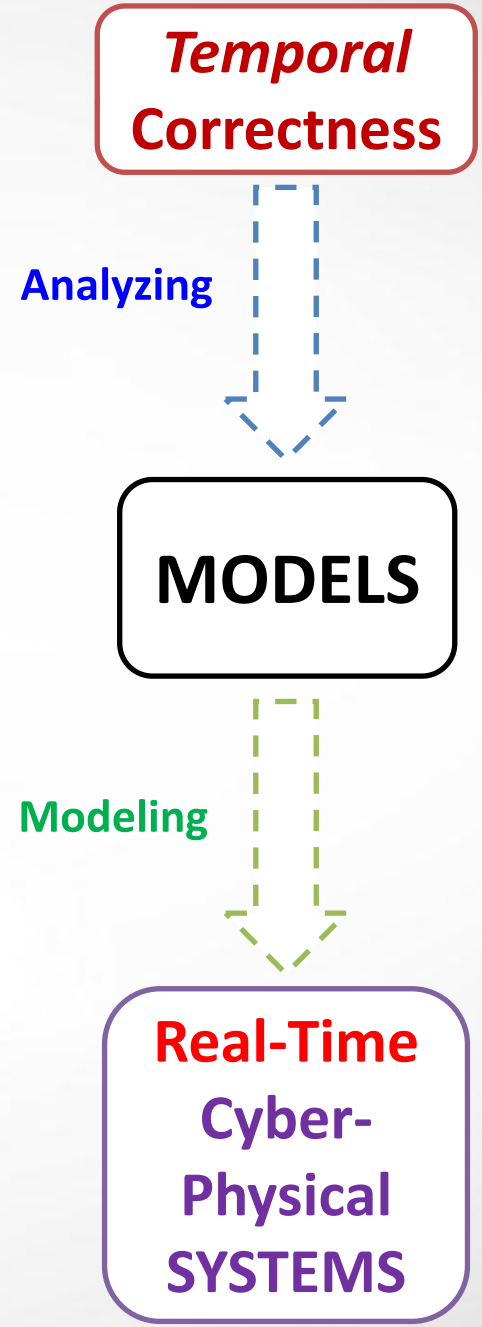
***Temporal* Correctness**

SAFETY-CRITICAL



Real-Time Cyber-Physical SYSTEMS

Models


Temporal Correctness
Analyzing
MODELS
Modeling
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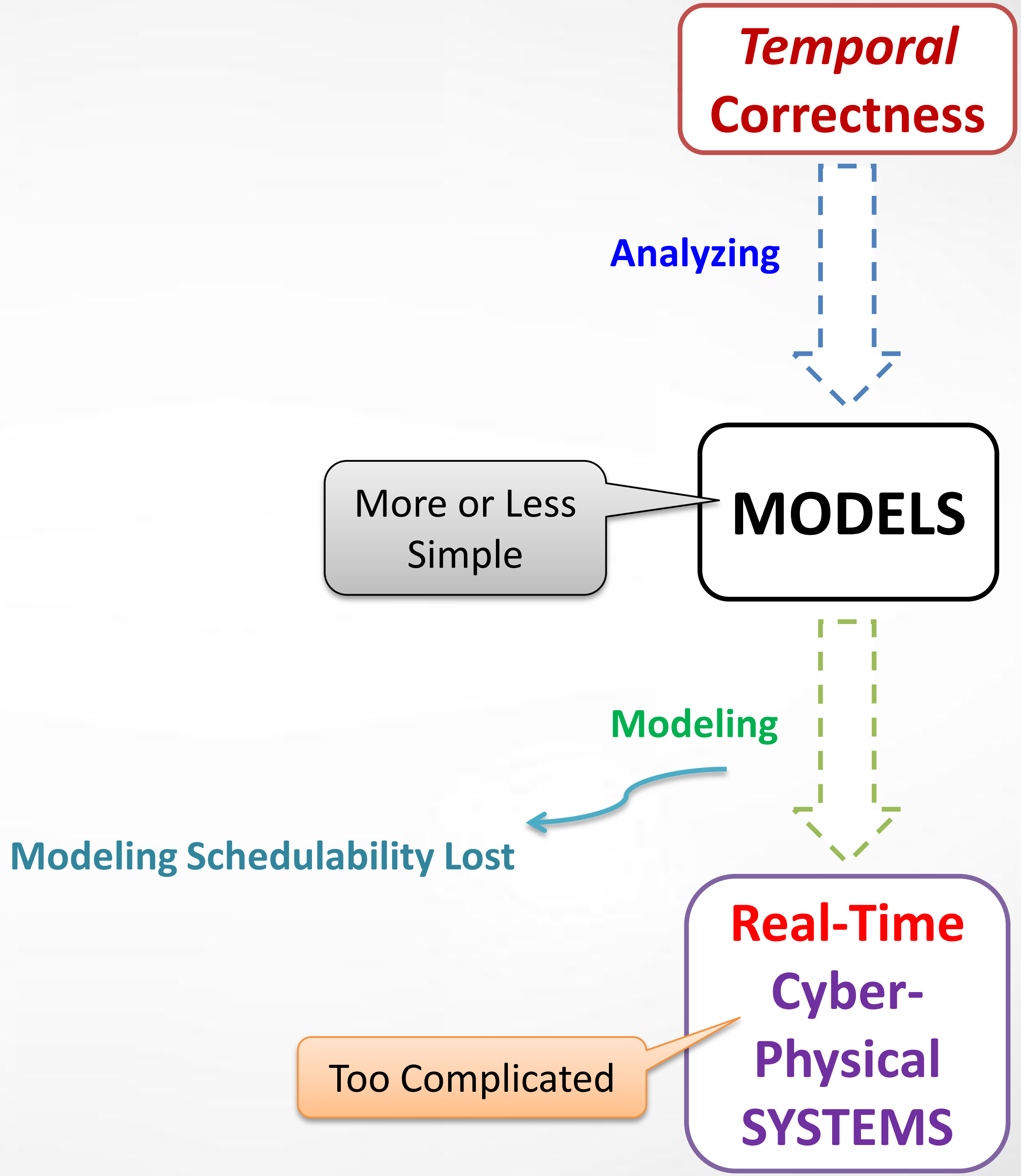
Models


Temporal Correctness
Analyzing
More or Less Simple
MODELS
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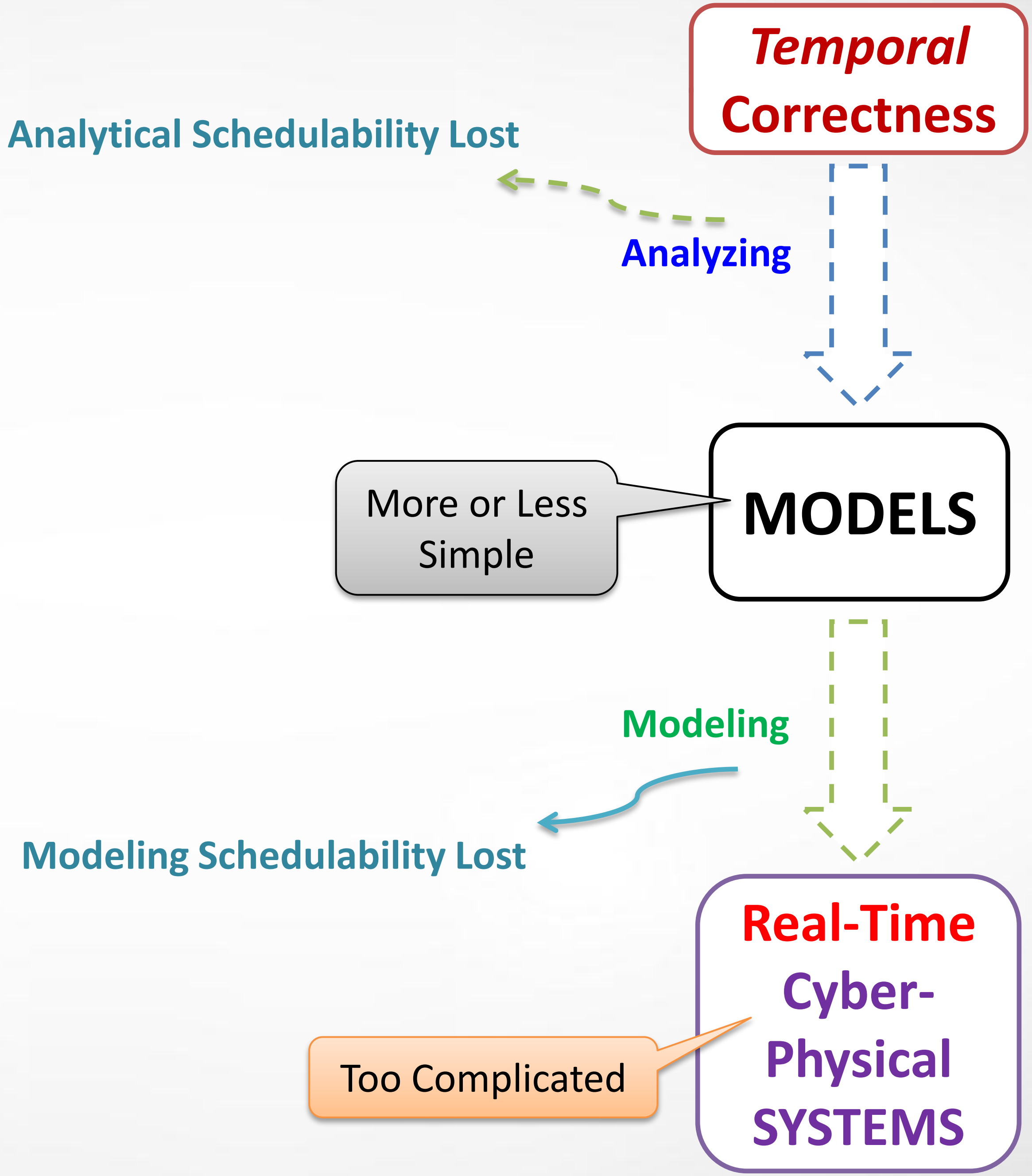
Modeling Schedulability Lost
Too Complicated
Real-Time Cyber-Physical SYSTEMS

Models



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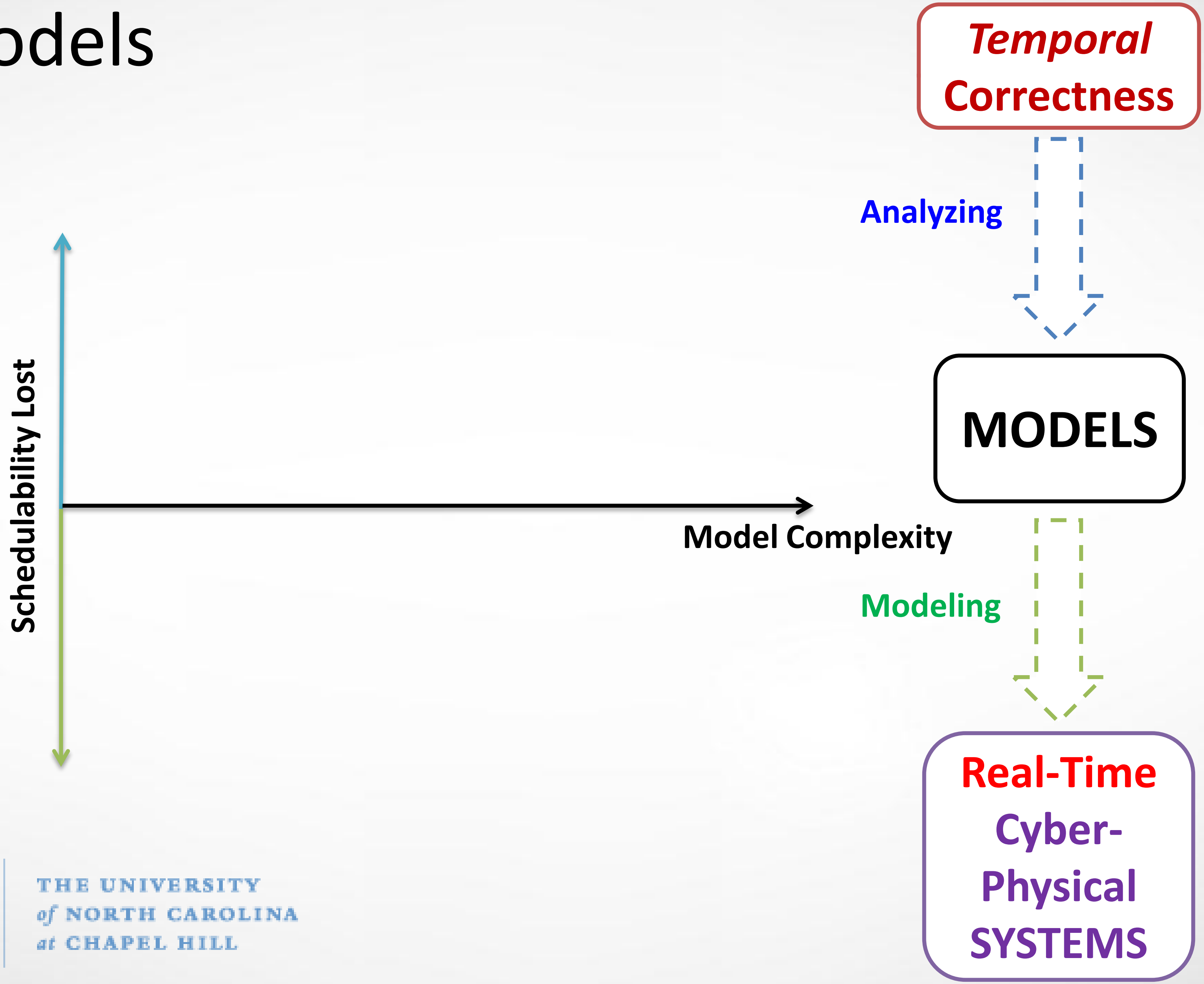

Temporal Correctness
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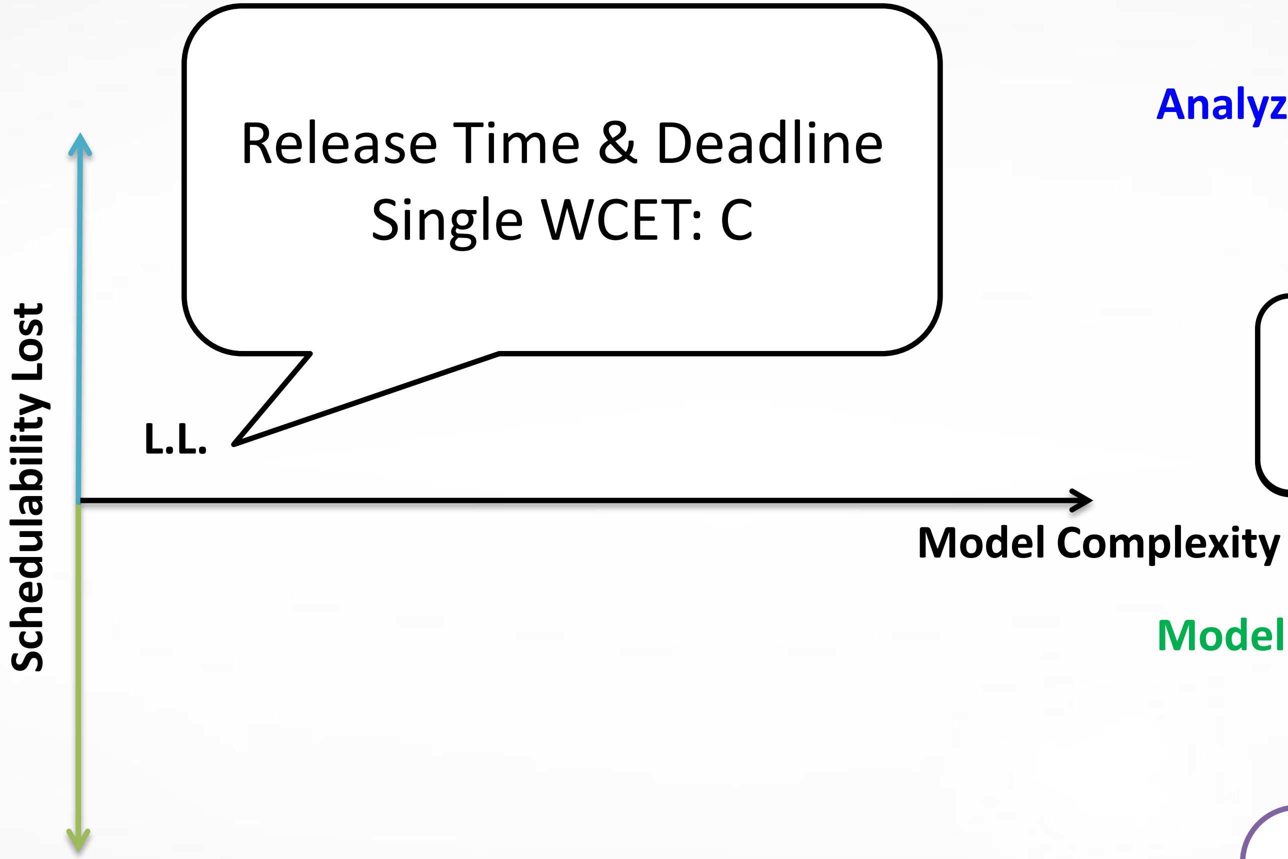
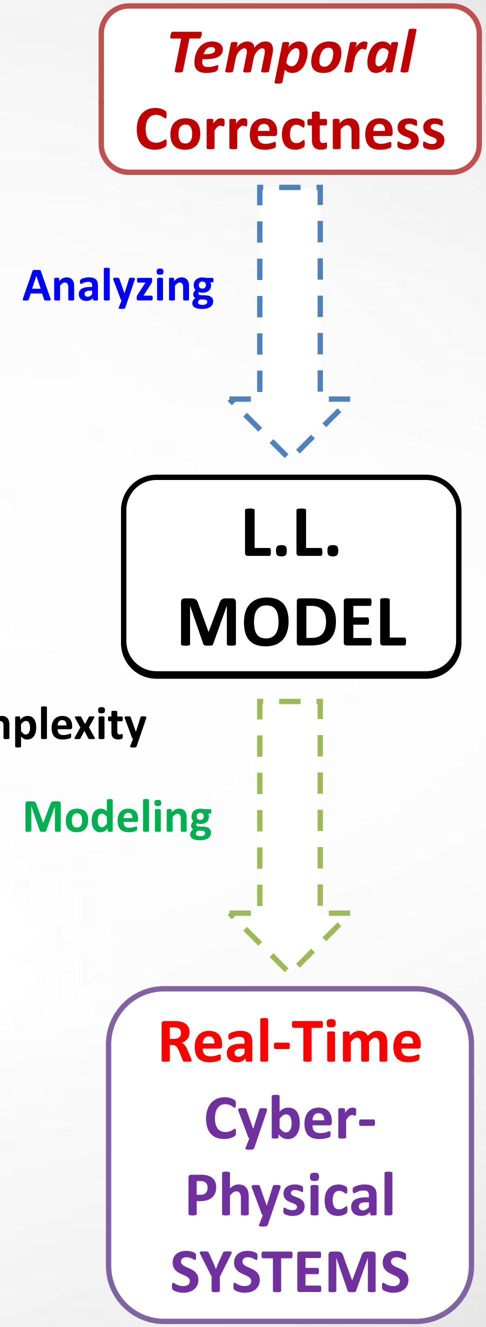
Real-Time Cyber-Physical SYSTEMS
Schedulability Lost
Model Complexity

Models


Release Time & Deadline
Single WCET: C
L.L.
Schedulability Lost
Model Complexity


Temporal Correctness
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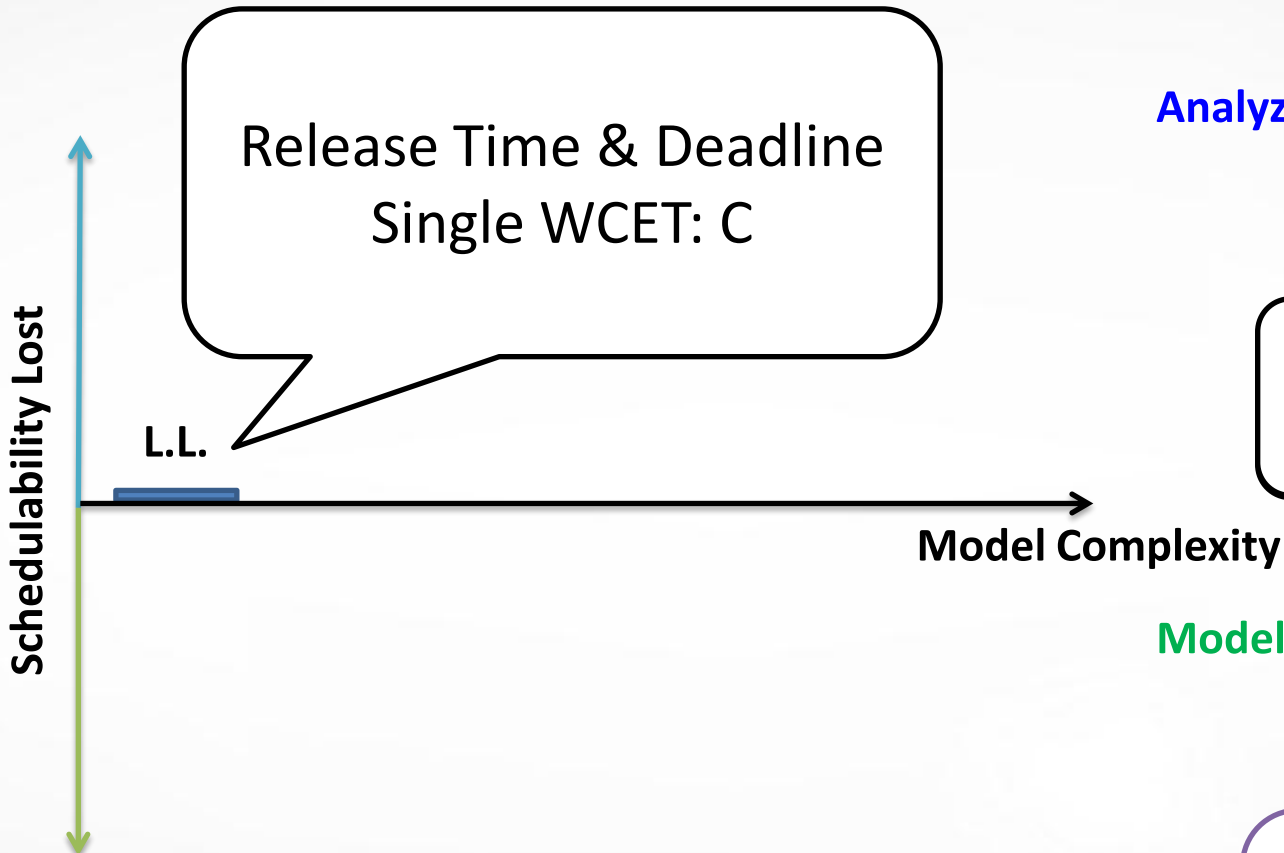
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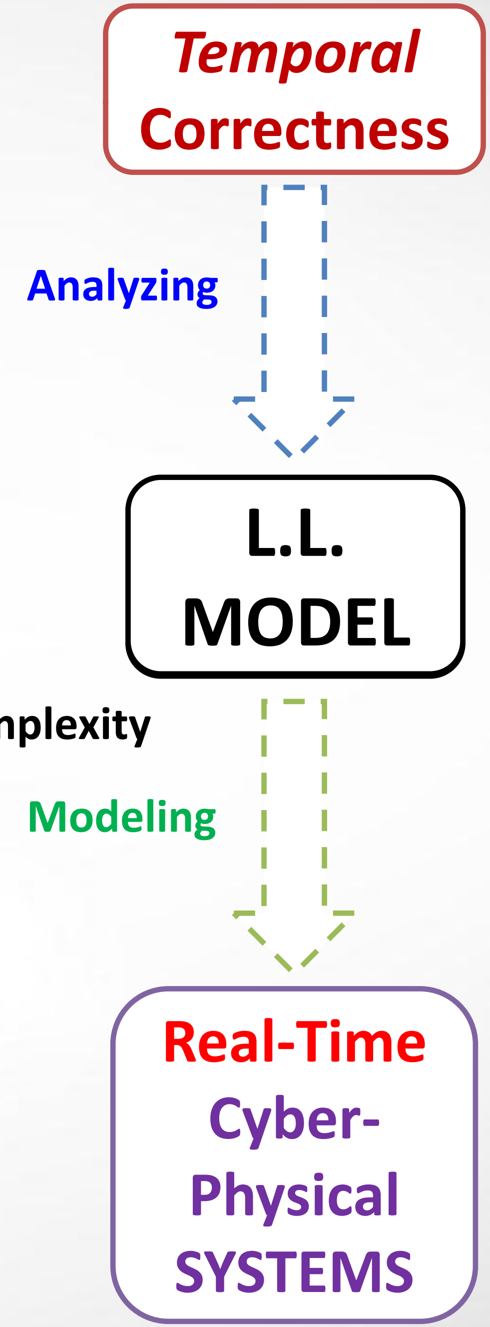
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Models

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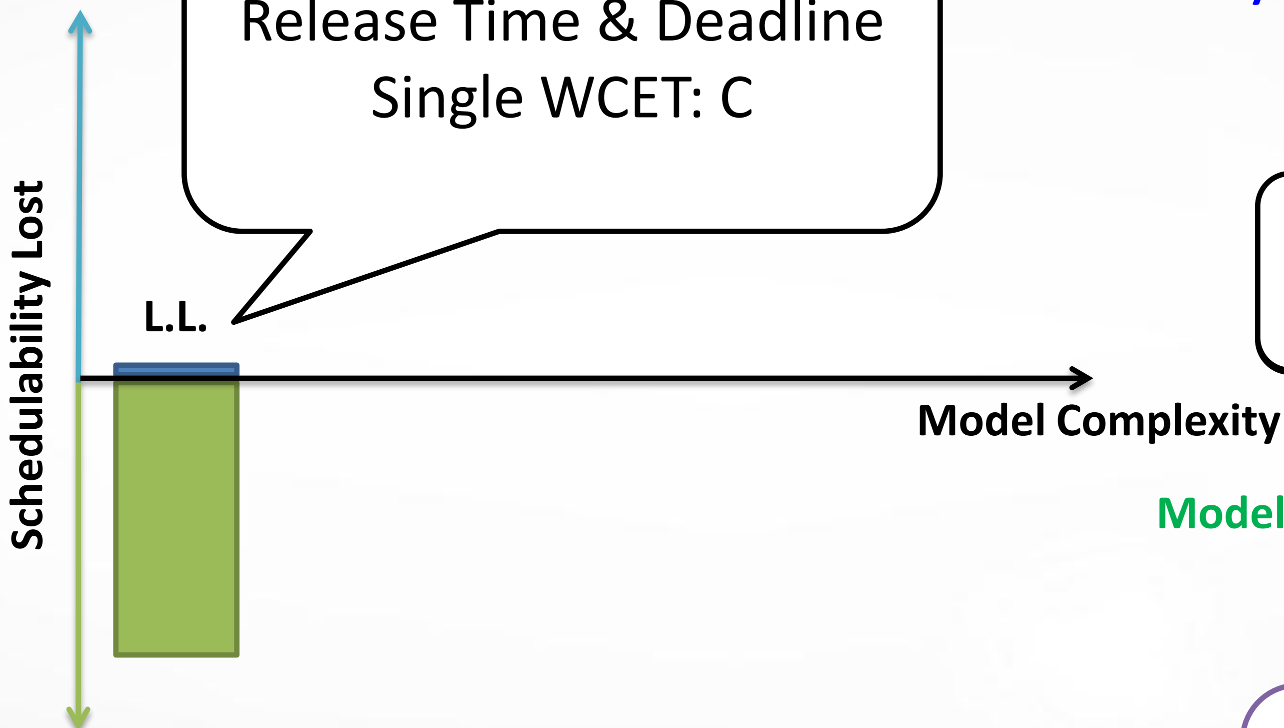


Temporal Correctness

Analyzing

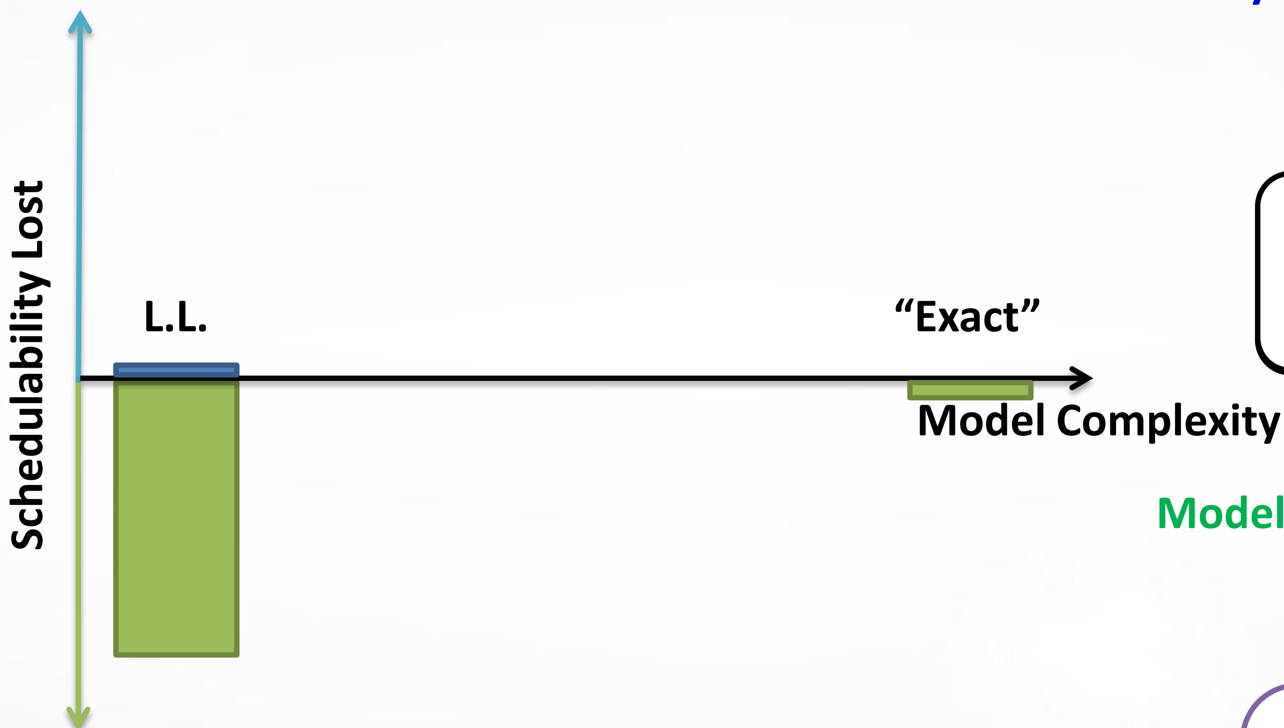
L.L. MODEL

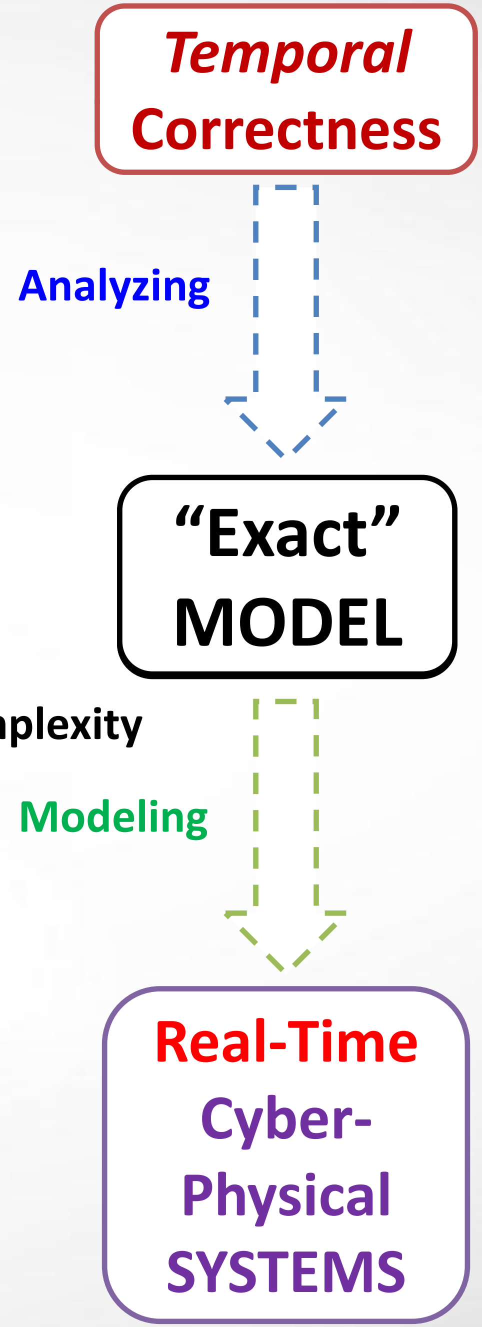
Modeling

Real-Time Cyber-Physical SYSTEMS

Example: x := a + b
3~9~321 cycles

Models


Schedulability Lost
L.L.
"Exact"
Model Complexity


Temporal Correctness
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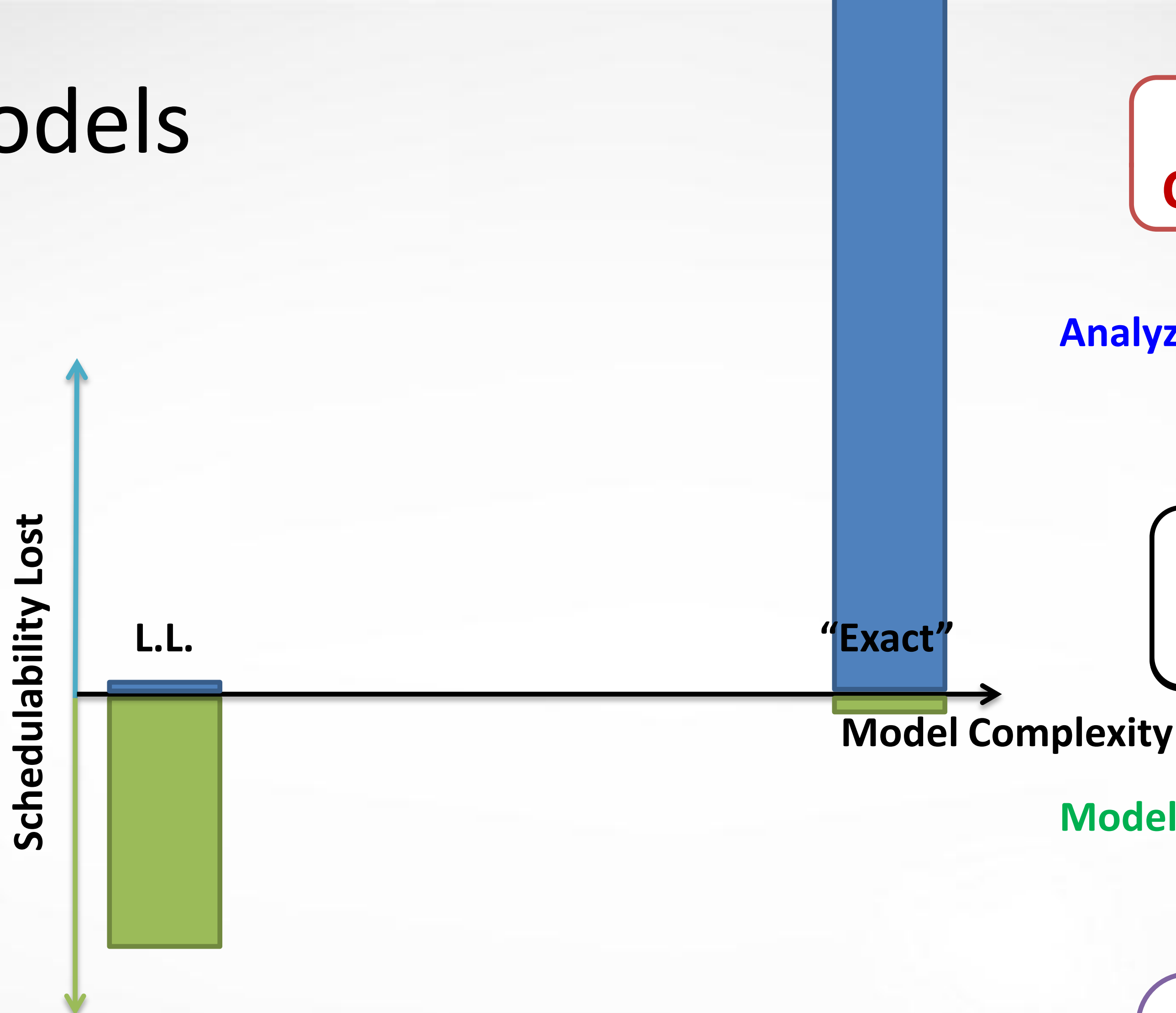
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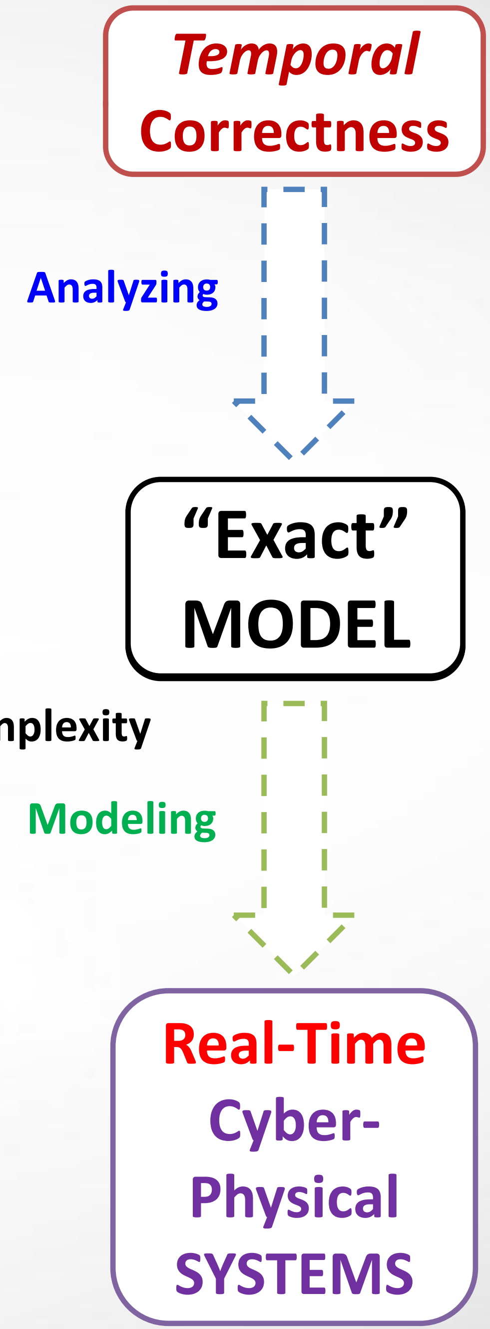
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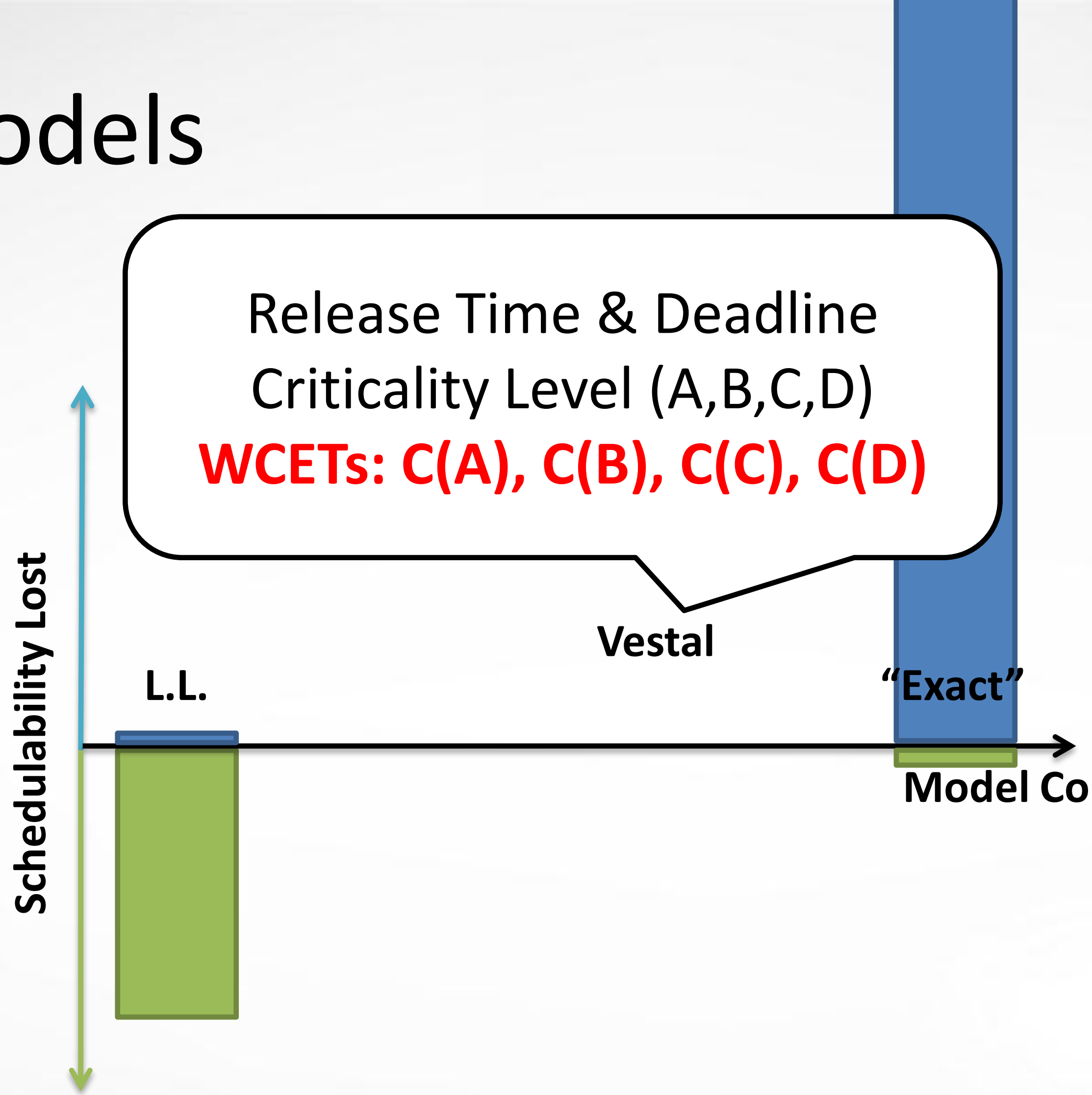

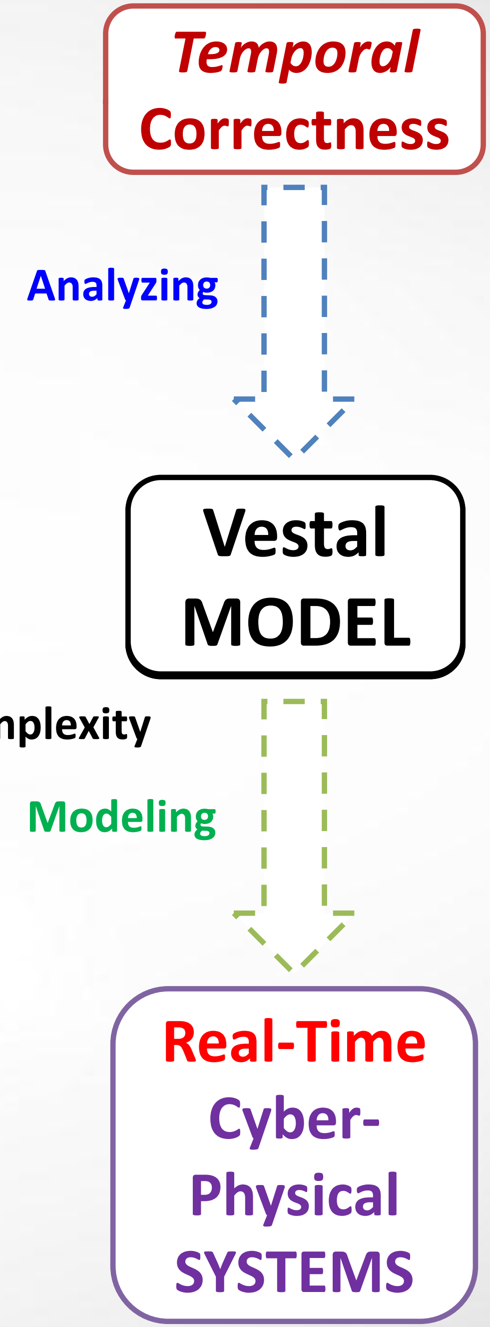

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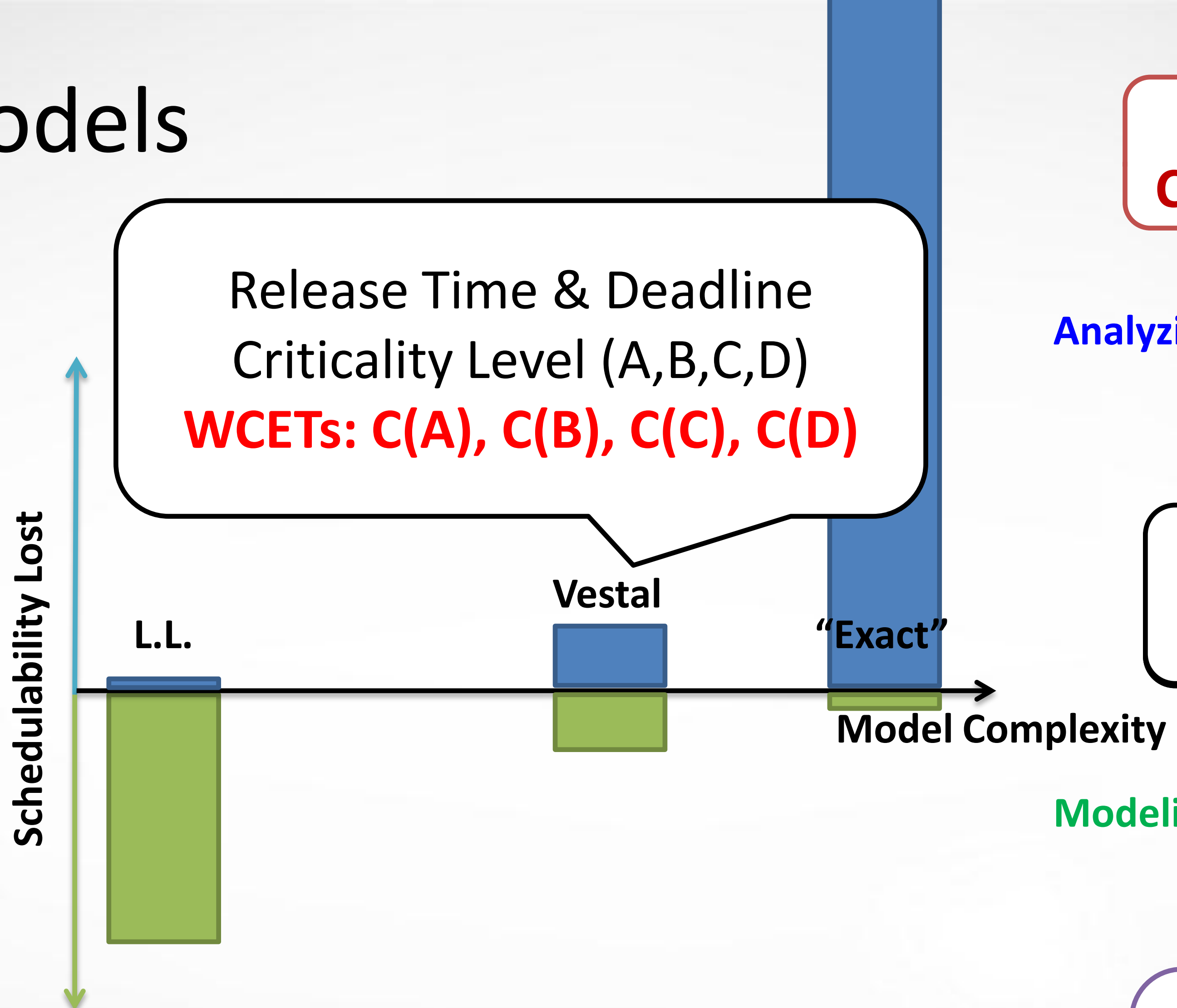
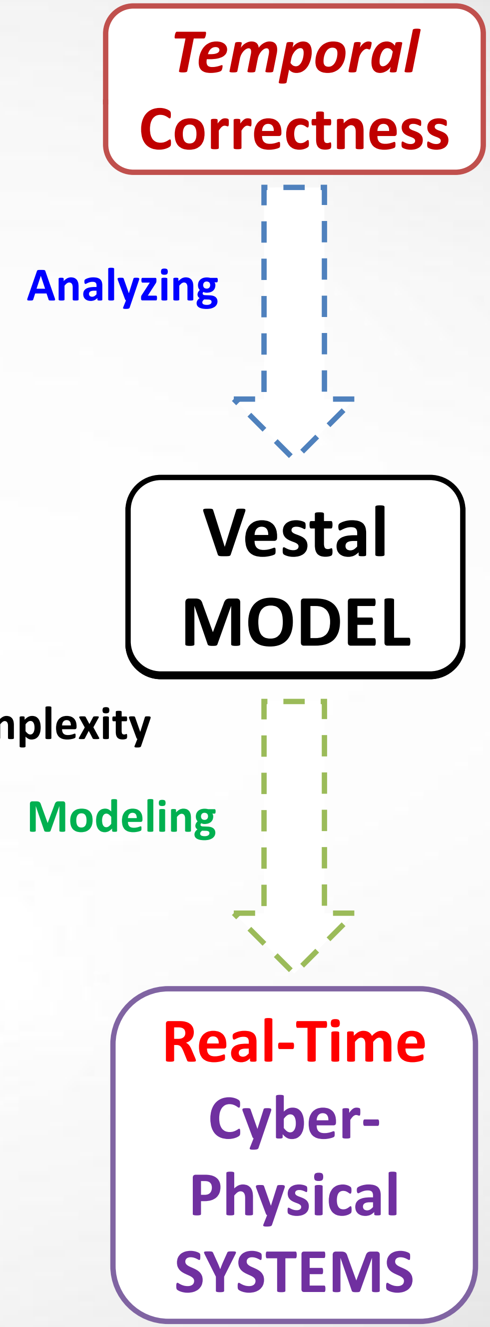
Models



Release Time & Deadline
Criticality Level (A,B,C,D)
WCETs: C(A), C(B), C(C), C(D)
Schedulability Lost
L.L.
Vestal
"Exact"
Model Complexity



Temporal Correctness
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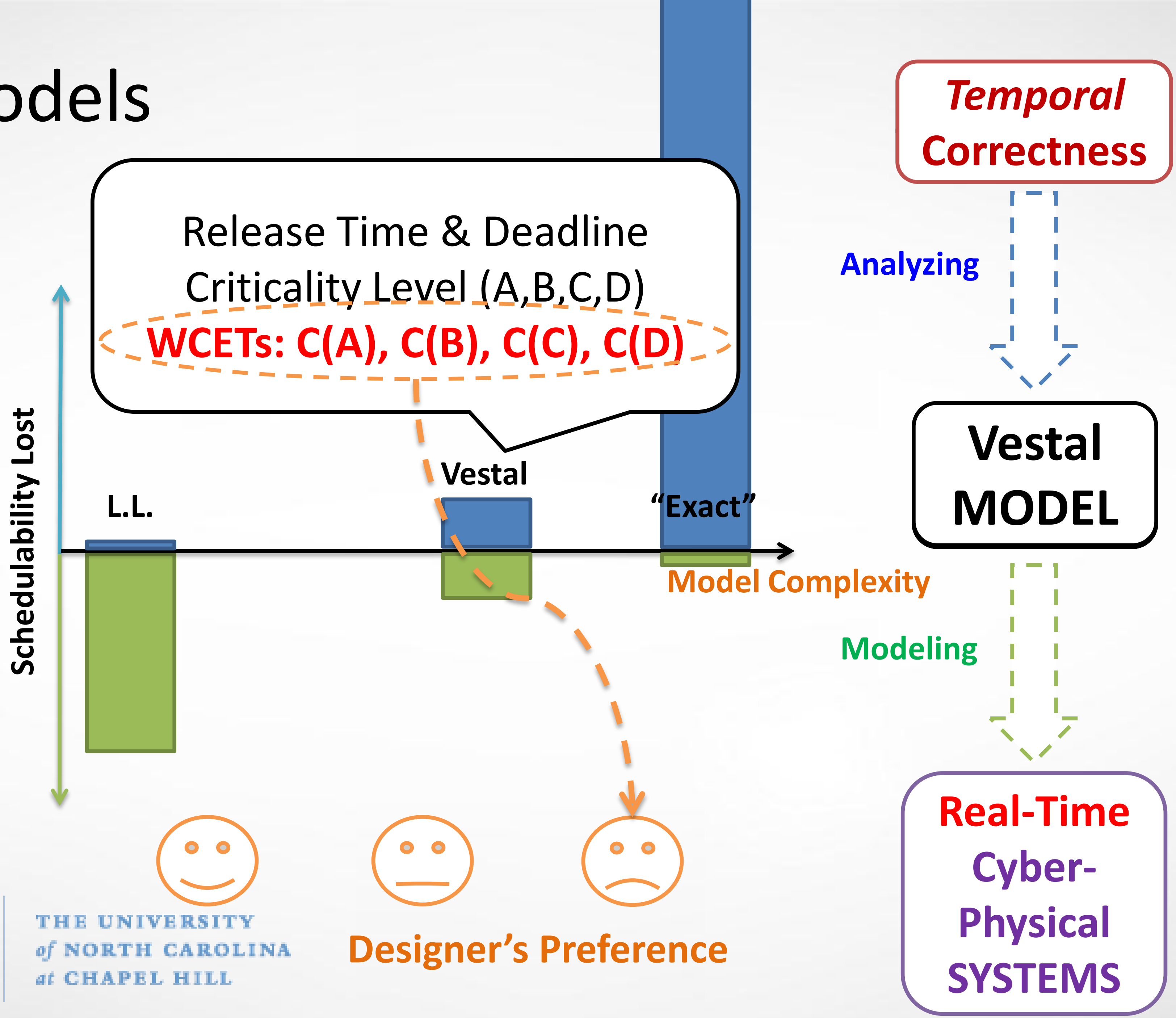

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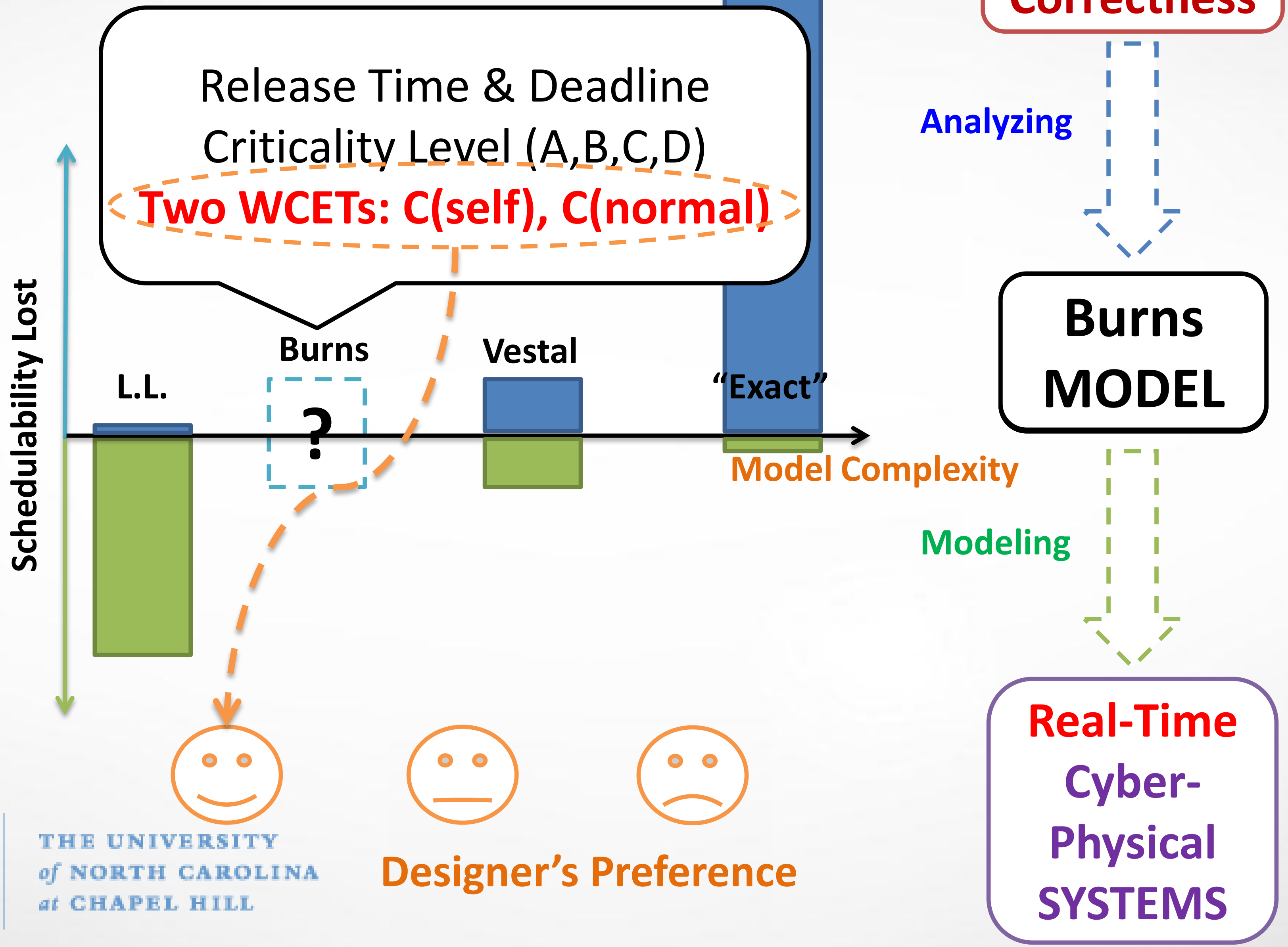
Models


Release Time & Deadline
Criticality Level (A,B,C,D)
Two WCETs: C(self), C(normal)
Schedulability Lost
L.L.
Burns
?
Vestal
"Exact"
Model Complexity
Designer's Preference
Temporal Correctness
Analyzing
Burns MODEL
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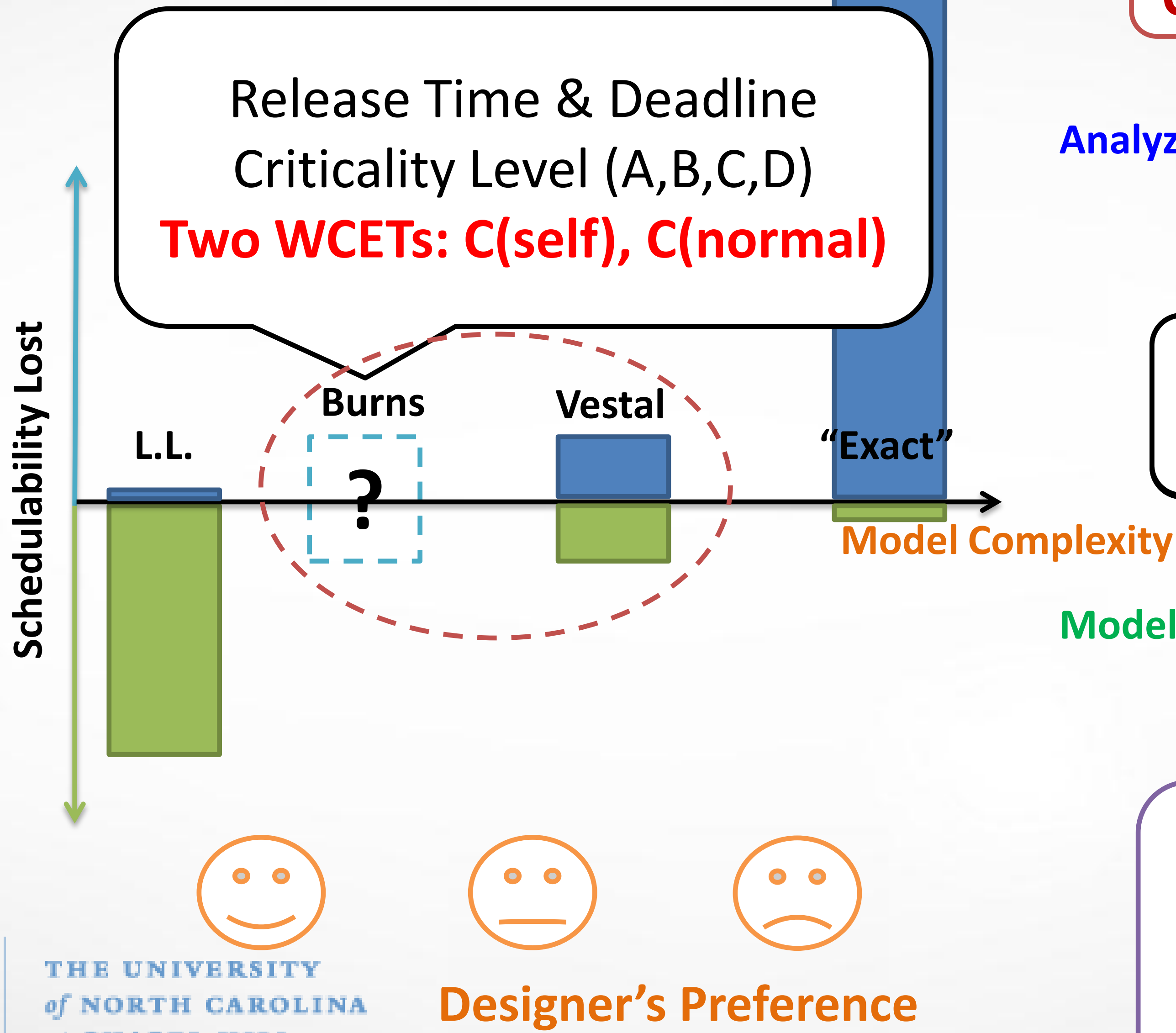

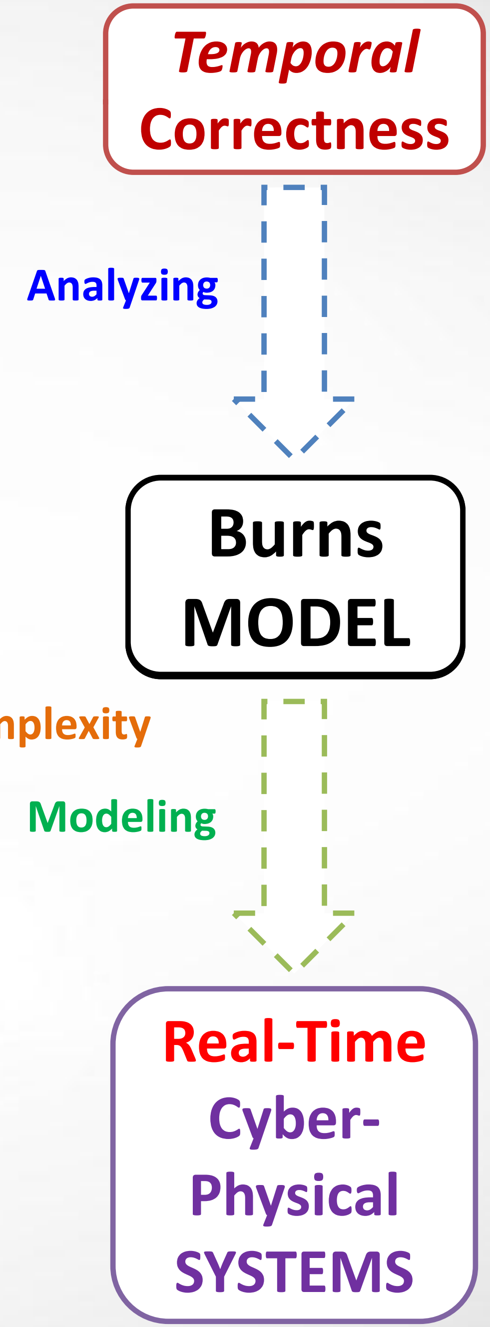

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Model Comparison

Vestal Model	***Burns Model***
*Criticality Levels χ_i: **A**, B, C, or **D***	
WCETs: $C_i(A)$, $C_i(B)$, $C_i(C)$, $C_i(D)$ 642, 321, 10, 5	

Example: x := a + b
3~9~**321** cycles

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WCETs:	Only **Two** WCETs:
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N/A, 321, 10, 5	321, 5

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N/A, N/A, 10, 5	10, 5

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Actual <u>execution time</u> remains unknown until the job *signals* its completion. (**non-clairvoyant**)

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Level of the System:= Smallest ℓ that $C_i(\ell)$ caps behavior of job i, $\forall$ i	**Level of the System**:= χ_i of the greatest-criticality job exceeding its C_i(NL)

Example: x := a + b
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Model Comparison

Temporal Correctness -- per level

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Model Comparison

Vestal Model	*Temporal* Correctness -- per level	*Burns Model*

Criticality Levels χ_i*: A, B, C, or D*

Vestal Model	Burns Model
WCETs:	Only **Two** WCETs:
$C_i(A)$, $C_i(B)$, $C_i(C)$, $C_i(D)$	$C_i(\text{self})$, $C_i(\text{normal})$
642, 5, 5, 5	642, 5

Proposition 1:
Any instance represented in the Burns model can be represented exactly in the Vestal model.

Example: $x := a + b$
3~9~321 cycles

Actual execution time remains unknown until the job *signals* its completion. (**non-clairvoyant**)

Model Comparison

Vestal Model	*Temporal* Correctness -- per level	*Burns Model*

*Criticality Levels χ_i: **A**, B, C, or **D***

WCETs:	Only **Two** WCETs:
C_i(A), C_i(B), C_i(C), **C_i(D)**	**C_i(SF)**, C_i(NL)
N/A, 321, 10, 5	321, 5

Proposition 2:
Instances represented in the Vestal model
cannot always be represented exactly in the Burns model.

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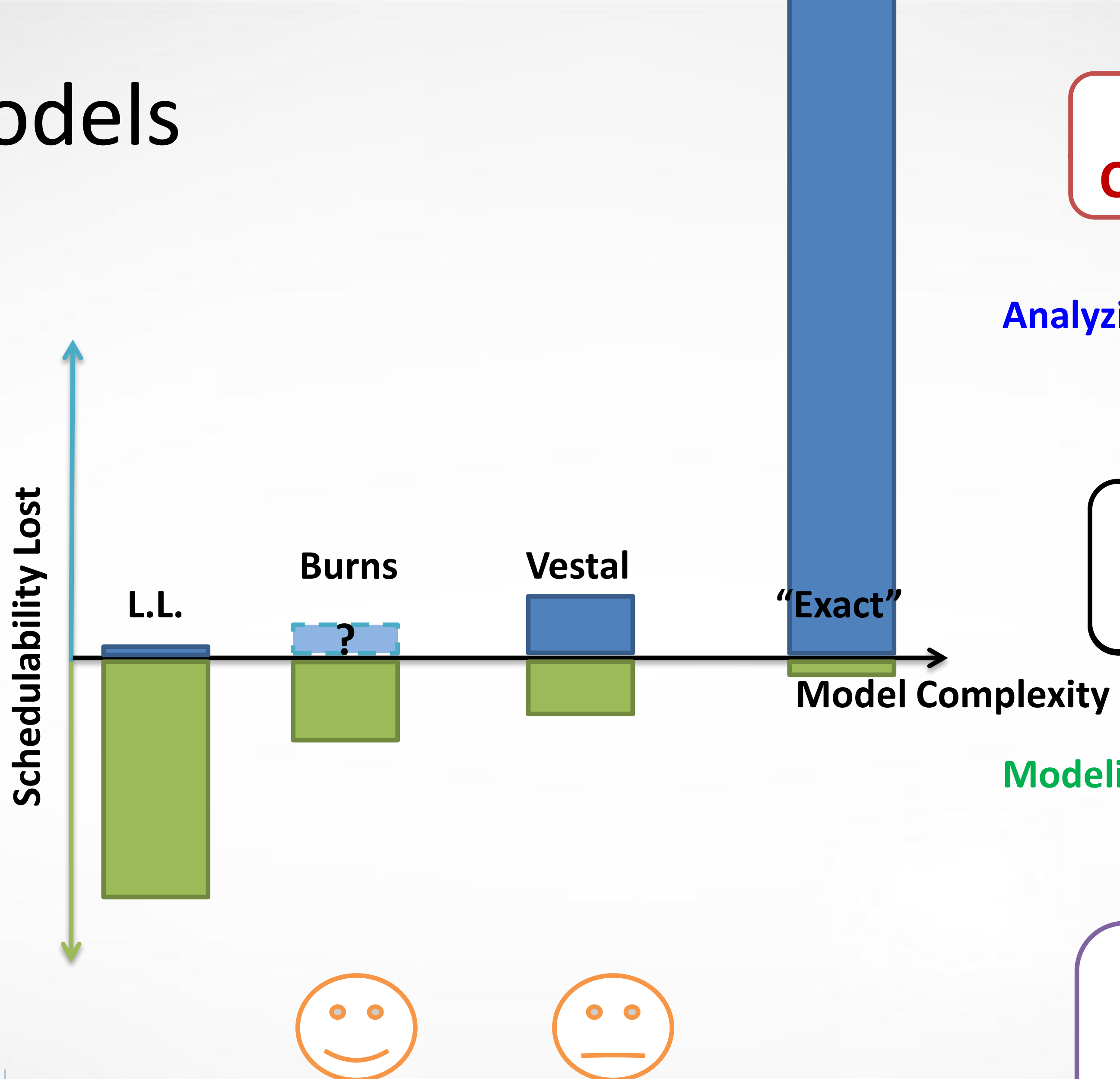
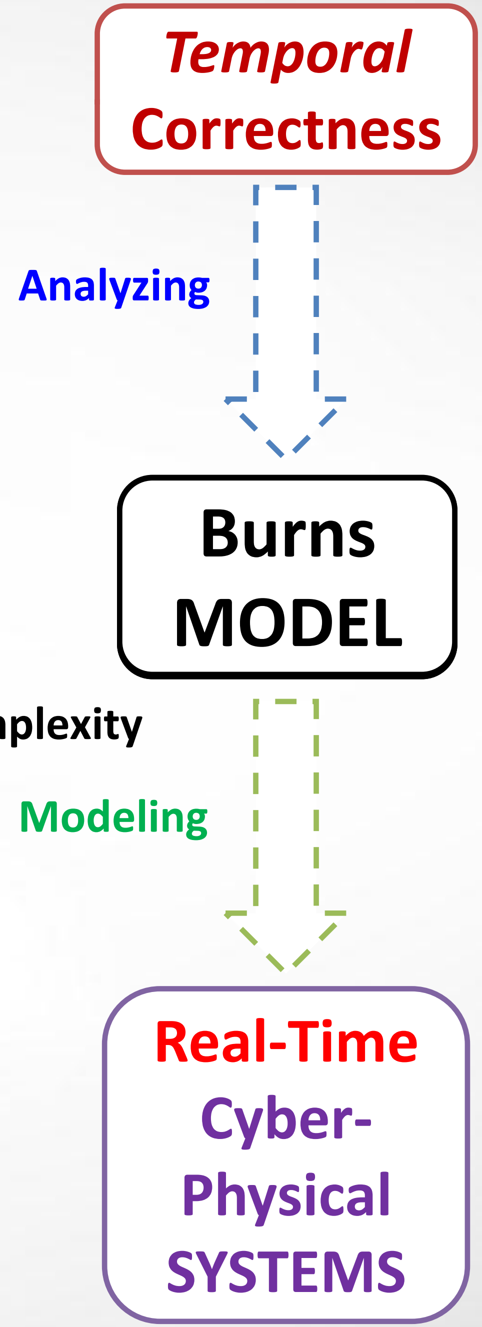
Models



Designer's Preference



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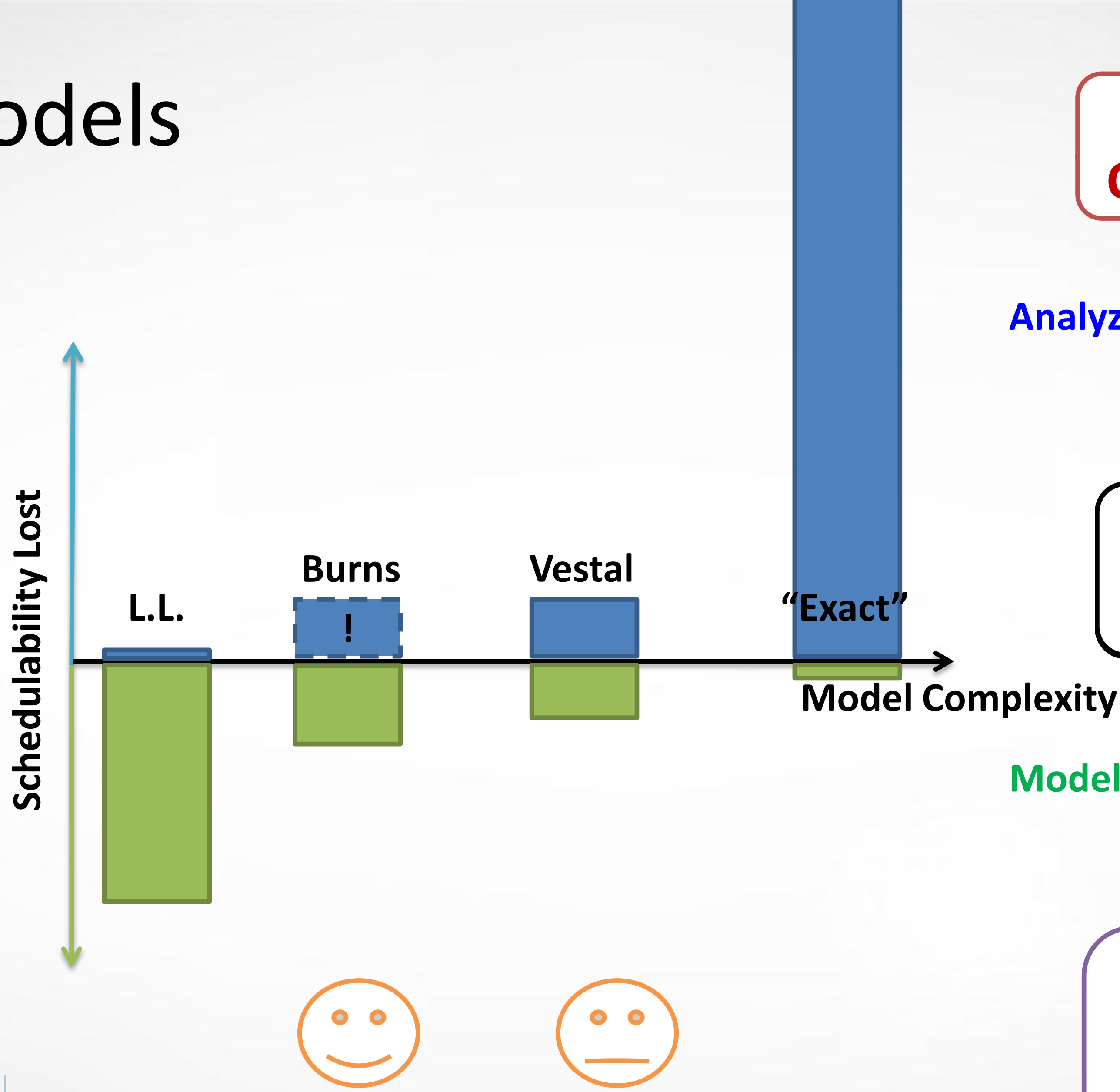

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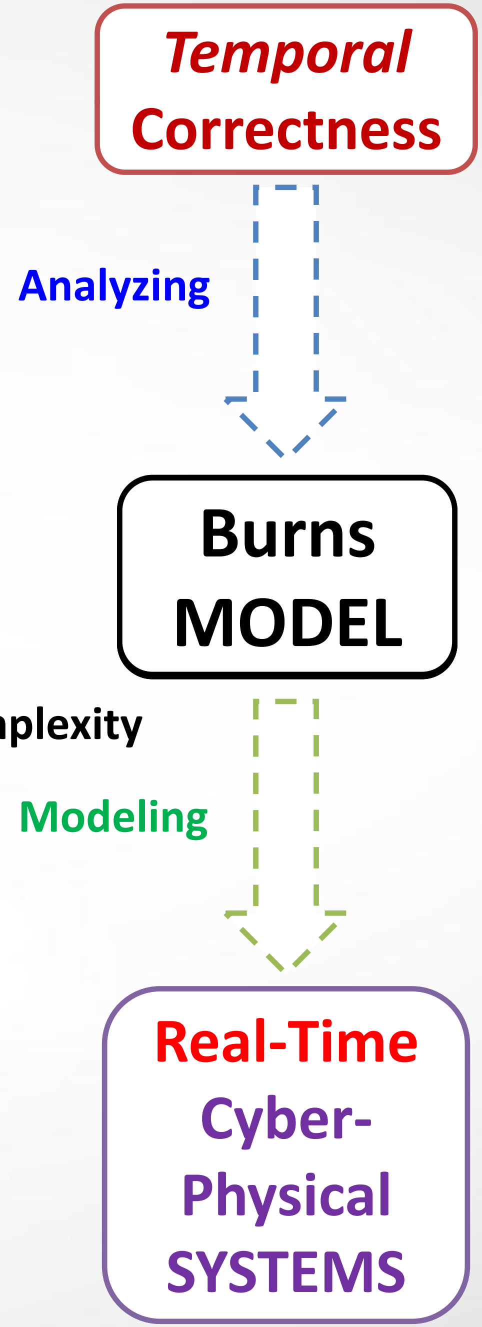

Model Comparison

Vestal Model	*Temporal* Correctness -- per level	***Burns Model***

*Criticality Levels χ_i: **A**, B, C, or **D***

WCETs:	Only **Two** WCETs:
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N/A, 321, 10, 5	321, 5

Proposition 3:
Determining whether a given instance specified according to the Burns model is MC-schedulable is NP-hard in s.s.

Model Comparison

Vestal Model	*Temporal* Correctness -- per level	*Burns Model*
	*Criticality Levels χ_i: **A**, B, C, or **D***	
WCETs:		Only **Two** WCETs:
C_i(A), C_i(B), C_i(C), C_i(D)		**C_i(SF)**, C_i(NL)
N/A, 321, 10, 5		321, 5

Thm 1:

There are MC instances with L distinct criticality levels specified using the Burns model that are clairvoyantly-schedulable, but that are not schedulable for any fixed priority policy on a processor that is less than s_L^* times as fast.

* s^L is the root of $x^L = (1 + x)^{L-1}$, i.e., the speedup bound under Vestal model.

Conclusion

- We seek to better understand the Ease-of-use Burns model.
- Unfortunately, we have not identified any analytical benefits in terms of reduced complexity of feasibility analysis, less schedulability loss, etc., at the cost of reduced expressiveness.

Conclusion & Future Work

- We seek to better understand the Ease-of-use Burns model.
- Unfortunately, we have not identified any analytical benefits in terms of reduced complexity of feasibility analysis, less schedulability loss, etc., at the cost of reduced expressiveness.
- Limitation: Fixed-Priority; Job Set; Uniprocessor.

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Thank you!

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