TE AI CUP 2025

Project Name

Team Name: AI Cup

University: The Ohio State University

Country: United States

TE Site:

EVERY CONNECTION COUNTS

Project Team

University Name: The Ohio State University
Team Name: AI Cup
University Advisor: Praveen Kumar
TE Advisor: Shu Wang

	Name	Grade	Major
Team leader	Cameron Dolson	4th	Computer Science
Team Member	Joseph Chiu	3rd	Computer Science
	JT Vendetti	4th	Computer Science
	Alyssa Haines	4th	Computer Science
	William Kim	4th	Data Analytics

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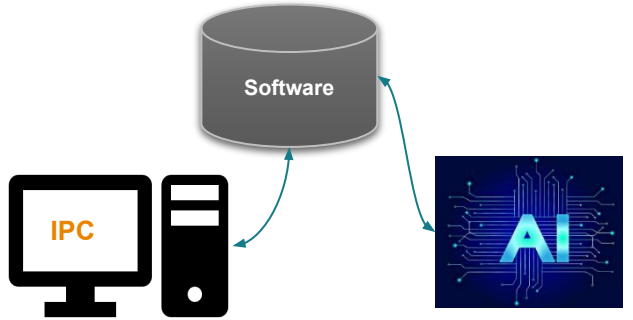
Selected Category



Category 1: AI Machine Vision (AIMV)

Category 2: AI Process Monitoring & Control

Category 3: General AI Applications

TE AI CUP 2024

Project Statement

- The TE Manufacturing Supply Chain is focused on production order scheduling, however orders are turning up late in big quantities and high amounts of revenue is lost.
- Our goal this semester was to develop a algorithm to aid in order scheduling, specifically focusing on minimizing
  - 1) Late Shortages
  - 2) The amount of changeover
  - 3) Overall production time

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Project Summary

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Summary

Problem Statement:

- Orders are turning up late and past due in big quantities.
- TE Manufacturing supply chain is looking to optimize the delivery process

Benefits:

- Optimized Weekly Schedule of centers
- Optimized Summary of Late Materials
  - Minimize Quality & Value

Potential Deployment:

- Supply Chain System Management having several plants and work centers
- Address late materials/late revenue using diverse scheduling approaches.

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Approaches

Priority Scheduling + Round Robin:

- Algorithm will generate one week production schedule for each center and will
- 1) Prioritize items that are at risk of being late
- 2) Alternate which orders get produced using timed intervals in order to allow every item to get produced (avoid starvation)

Optimization:

- Output/Objective Function:
  - PuLP: solving linear optimization problems
  - Minimize the work center penalties
- Decision variable per work center
  - 1 ⇒ material produced at hr *h*
  - 0 ⇒ otherwise
- Constraints:
  - Only one material can be procured at a time per work center
  - Total production hours can not exceed 168
  - Respect the required demand (Don't overproduce)

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Project Statement

Optimization Algorithm

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Results (Optimization) - Decision Variable

$$x_{m,h} = \begin{cases} 1 & \text{if material } m \text{ is produced at hour } h \\ 0 & \text{otherwise} \end{cases}$$

Each work center has matrix X

which has 1 if material m is produced at hour h in work center

$$x_{m,h}^{\text{before}} = \begin{bmatrix} 0 & 0 & 0 & \dots & 0 \\ 0 & 0 & 0 & \dots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \dots & 0 \end{bmatrix}$$

$$x_{m,h}^{\text{optimize}} = \begin{array}{c|ccccccccc} & h_1 & h_2 & h_3 & h_4 & h_5 & h_6 & h_7 & h_8 & h_9 \\ \hline A & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 0 \\ B & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 1 & 0 \\ C & 1 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 1 \end{array}$$

Before we optimize the problem, X is scheduled yet (all zeros).

After solver optimize it, X should represent the schedule of specific work center.

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Results (Optimization) - Objective Function

$$\text{Objective Function} = \sum_{\text{Material } m} (\text{required production} - \text{total produced}) \times \text{priority weight}$$

1. required production = |reqbal_wk1| if reqbal_wk1 < 0 (negative)
   pass(not included) otherwise (reqbal_wk1 >= 0)

2. total produced = sum of rows * rate

$$\text{TotalProduced}_m = \sum_{h=1}^{168} x_{m,h} \times r_m$$

3. priority weight:

$$W_m = 1,000,000 \times \frac{1}{p_m}$$

Material	Priority p_m	Priority Weight W_m
A	1	1,000,000
B	2	500,000
C	5	200,000

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Results (Optimization) - Example

```
work_center_penalties = [
        (300 - 300) * 1,000,000        # Material 1
        (200 - 200) * 500,000          # Material 2
        (400 - 200) * 200,000          # Material 4
]
work_center_penalties = [0, 0, 40,000,000]
```

- Material 1 required to produce 300 units and totally 300 units are produced
- Material 2 required to produce 200 units and totally 200 units are produced
- Material 3 is not included (pass) in the work_center_penalties because it has positive reqbal_wk1.
- Material 4 required to produce 400 units, but only 200 units are produced

- Solver will look for the optimal X (Decision Variable) to minimize work_center_penalties as much as possible.
- Solver will start to minimize material that has higher priority to minimize it.

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Results (Optimization) - Constraints

Constraint 1: Only one material can be produced at a time

$$\sum_{m} x_{m,h} \leq 1$$

- Sum of columns (materials) should be less than or equal to 1
- At most one material is produced at any hour in work center.

Constraint 2: Total production hours cannot exceed 168

$$\sum_{m} \sum_{h=1}^{168} x_{m,h} \leq 168$$

- Sum of all elements should be less than or equal to 168
- Weekly production capacity is limited to 168 hours total

Constraint 3: Don’t over-produce materials (respect the required demand)

For each material m where $\text{reqbal\_wk1}_m < 0$:

Let $R_m = |\text{reqbal\_wk1}_m|$ and $r_m = \text{ratephr}_m$

$$\sum_{h=1}^{168} x_{m,h} \cdot r_m \leq R_m$$

- Don’t produce more than the required production (|reqbal_wk1|)

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Results (Optimization) - make_schedule_continuous

- The optimized result from solver do not take into account for continuous production of each material and changeover.

$x_{m,h}^{\text{optimize}} =$

	h_1	h_2	h_3	h_4	h_5	h_6	h_7	h_8	h_9
A	0	0	1	0	0	1	0	0	0
B	0	1	0	0	1	0	0	1	0
C	1	0	0	1	0	0	1	0	1

- make_schedule_continuous function rearrange the schedule to

1. ensure each material is scheduled in a continuous block to minimize changeover.
2. ensure that schedule is starting with highest priority material from hour 1

$x_{m,h}^{\text{after}} =$

	h_1	h_2	h_3	h_4	h_5	h_6	h_7	h_8	h_9	h_{10}	h_{11}	h_{12}
A	1	1	0	0	0	0	0	0	0	0	0	0
B	0	0	0	0	1	1	1	0	0	0	0	0
C	0	0	0	0	0	0	0	0	0	1	1	1

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Results (Optimization) - Improvement

- Reducing constraints and decision variables is crucial for efficiency and running time of algorithm.
- By using combined objective function and additional function (make_schedule_continuous) for schedule rearrangement,

  solver doesn't need to consider the continuous scheduling, changeover and priority rank of materials for optimization.
- Different combination and weight for objective function can cover diverse and non-rigid constraints without actual constraints in solver.

Example

- We can weight reqbal_wk1 and reqbal_wk2 in objective function to cover upto week2.

$$\text{Minimize} \quad \sum_{m} \left(1000 \cdot (\text{reqbal\_wk1}_m + \text{produced}_m) + 200 \cdot (\text{reqbal\_wk2}_m + \text{produced}_m)\right)$$

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Project Statement

Scheduling Algorithm

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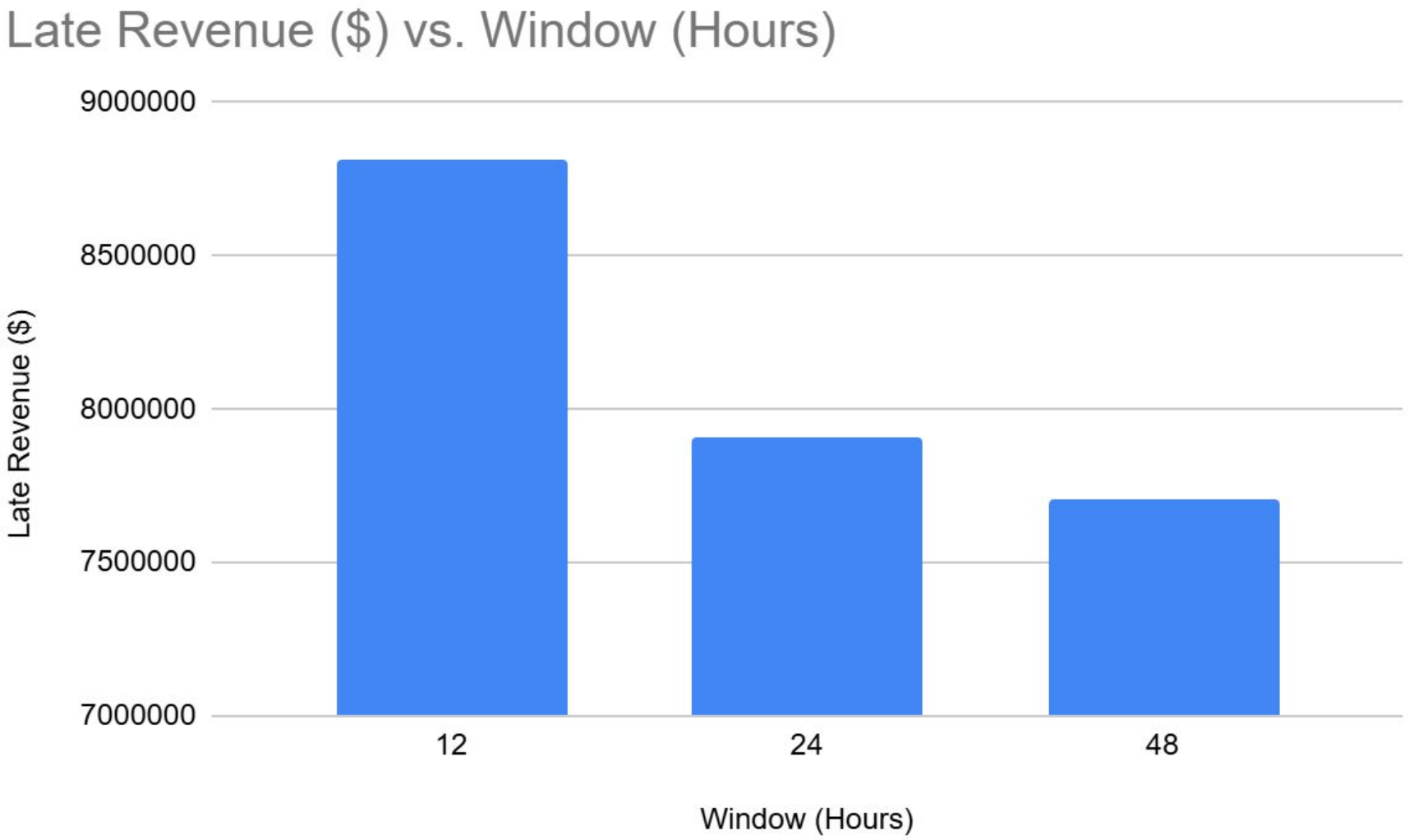
Results (Priority Scheduling + Round Robin)



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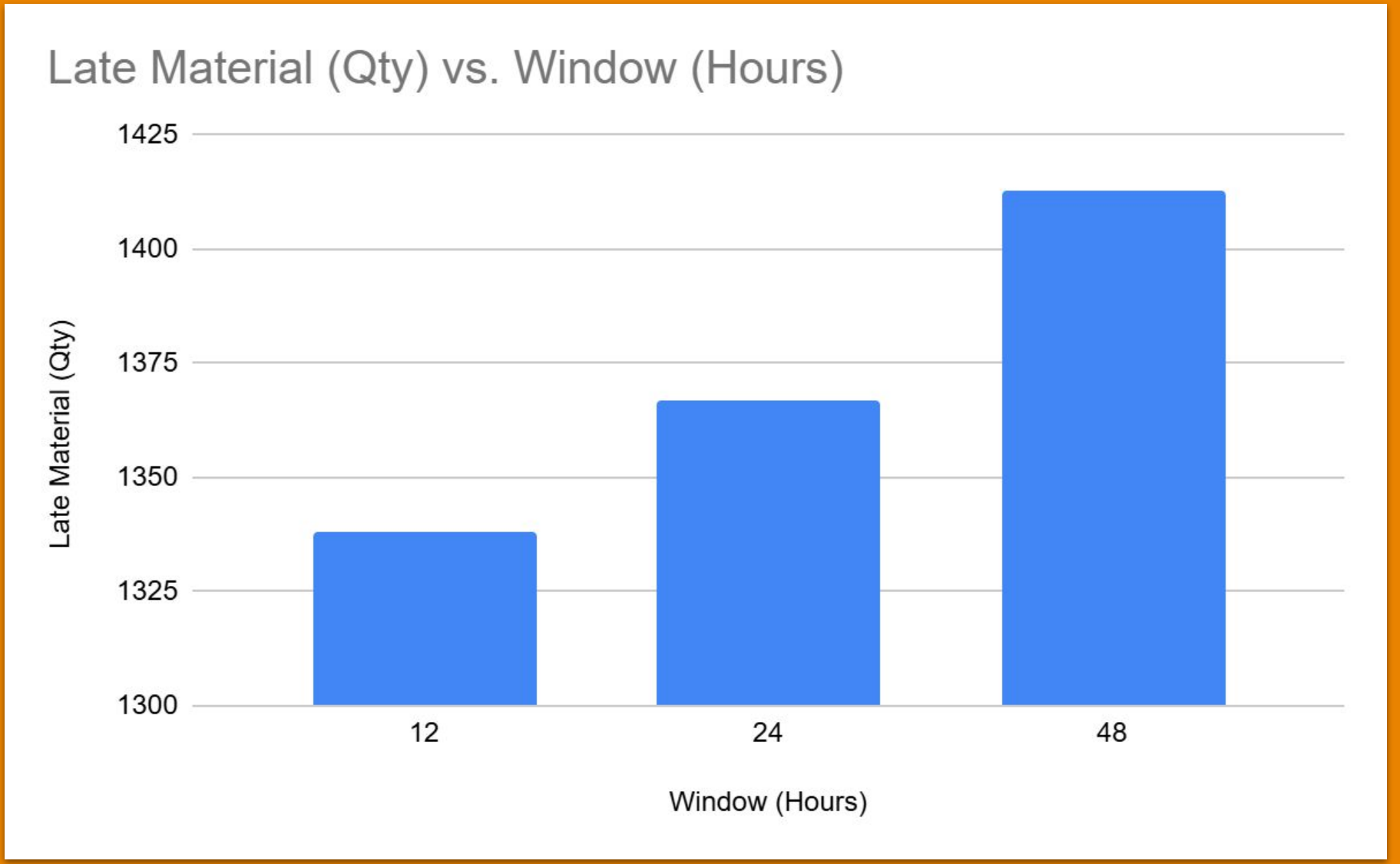
Results (Priority Scheduling + Round Robin)



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Results (Priority Scheduling + Round Robin)

Compared to the previous algorithm without Round Robin

- Late Materials decreased from 1444 materials to:
  - Average: 1372 (-72)
  - Max: 1338 (-106)
- Late Revenue increased from 4.2 million to:
  - Average: 8.1 million (+3.9)
  - Max: 8.8 million (+4.6)

Late revenue may seem shocking at first, but this can be accounted for

- Our estimation formula
- Producing lower priority materials
- Adding a changeover penalty (~12 hours lost per WC)

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Innovation Description

- The implementation of a priority scheduling with round robin scheduling algorithm has not been implemented in a manufacturing context
- Based on the above results, we are moving forward with the priority/ round robin hybrid algorithm as this implementation has shown the best results
- This implementation will ensure that all of the materials for the week are accounted for and processed based on the correct priority

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Application Features and Business Value

- **AI Innovation**
  - *Incorporates multiple scheduling algorithms to optimize delivery*
  - *Schedules deliveries accordingly and calculates total late items & revenue*

- **Benefits to TE/Industry**
  - *Improves efficiency of delivery and ensures less late orders & revenue*
  - *Saves companies millions of dollars in late revenue*
  - *(Late value / Quantity) * Late Revenue for One Week (Substitute with Correct Formula in the Future)*

- **Deployment Opportunity**
  - *Carrier services can incorporate our algorithm to improve delivery rates*
  - *Delivery routes can be optimized with our algorithm before deployment of packages*

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Scorecard

Item	Content				Weight	Score	Sum
AI Innovation	Method is New in Industry	Method is New to TE	Improving Method	Existing Method	1.5	10	15
	10	7	4	1			
AI Algorithm	Innovative neural network/algorithm	Improved neural network/algorithm based on existing ones	Using exisiting network/algorithm		1.5	10	15
	10	7	3				
ROI *Return on Investment*	≤ 0.5 Years	0.5 ~ 1.0 Year	1.0 ~ 1.5 Years	> 1.5 Years	1	10	10
	10	7	4	1			
Deployment Opportunities in TE	≥50	30 ~ 50	10 ~ 30	1 ~ 10	1	10	10
	10	7	4	1			
Business Impact (in US$) on TEBIT Savings and Revenue *(by Current Projects)*	≥ 100K	50K ~ 100K	20K ~ 50K	< 20K	1	10	10
	10	7	4	1			
Benefits	Accuracy/Quality/Process Variation Improvement	Efficiency Improvement	EHS Improvement		0.5	10	5
	Plus 5	Plus 3	Plus 2				
Production Readiness *How Soon to Launch Production*	Running on Real Use Cases	Trial Run	sful Validation with Running Plan Av	Weak Validation	2	10	20
	10	7	4	1			
Carbon Emission Reduction	Energy Saving	Material Saving	Others		0.5	10	5
	Plus 4	Plus 4	Plus 2				
Special Rewarding Score *Achieving excellent achievements in business impact, TEBIT number, patents, etc.*	Student teams list TEBIT number / patent here if ready for the jurors's reference				1	10	10
						Total Score	**100**

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CONNECT LIKE THE WORLD DEPENDS ON IT. BECAUSE IT DOES.

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