Reflections on the State of Development of Connected and Automated Driving (CAD)

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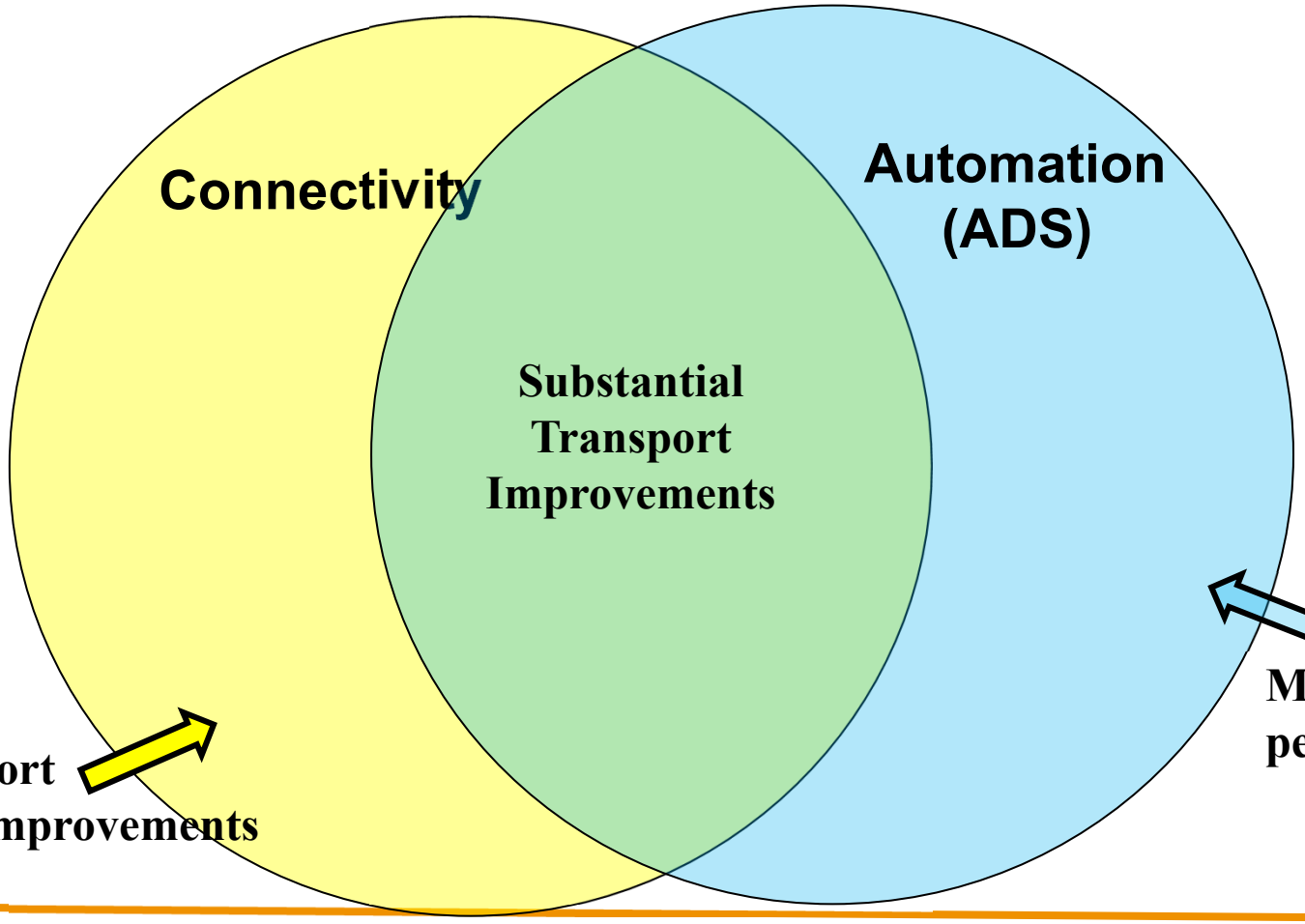
Ghent, June 18, 2024

Connectivity and Automation



Modest transport performance improvements

Mixed (+/-) transport performance impacts

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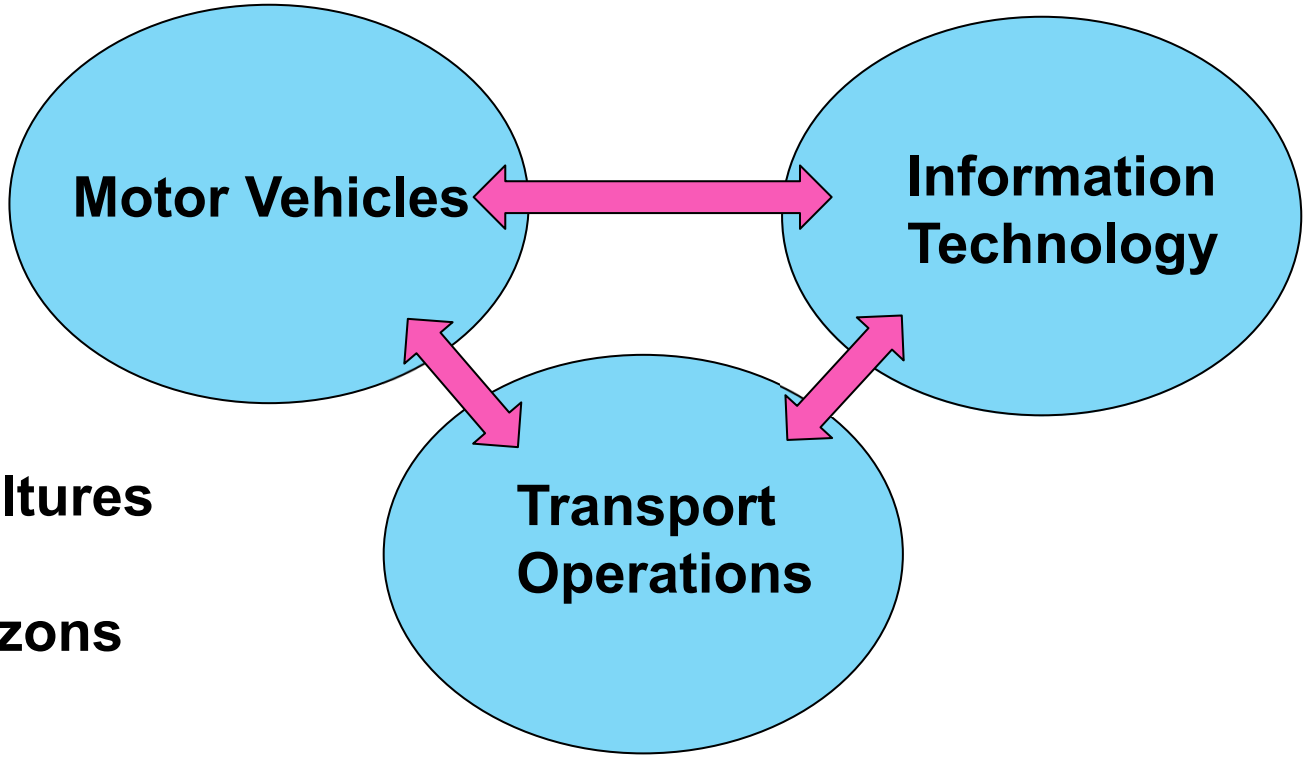
CAD is a Hybrid of 3 Industries



Diversity of:

- Organization cultures
- Priorities
- Investment horizons
- Public images
- Risk tolerance
- Attitudes toward safety

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Automated Driving Development Challenges

- Complexity of driving environment
  - Geographic diversity of driving behaviors → scalability?
- Perception technology limitations
- Software development, verification and validation methodology limitations
  - Substituting human engineering errors for driving errors
- High safety requirements → redundancy → cost

  Need to exceed baseline human driving safety:
  - (US): 1 fatal crash in >400 years of 24/7 driving
  - (US): 1 injury crash in 7 years of 24/7 driving
- Competition with electrification for resources

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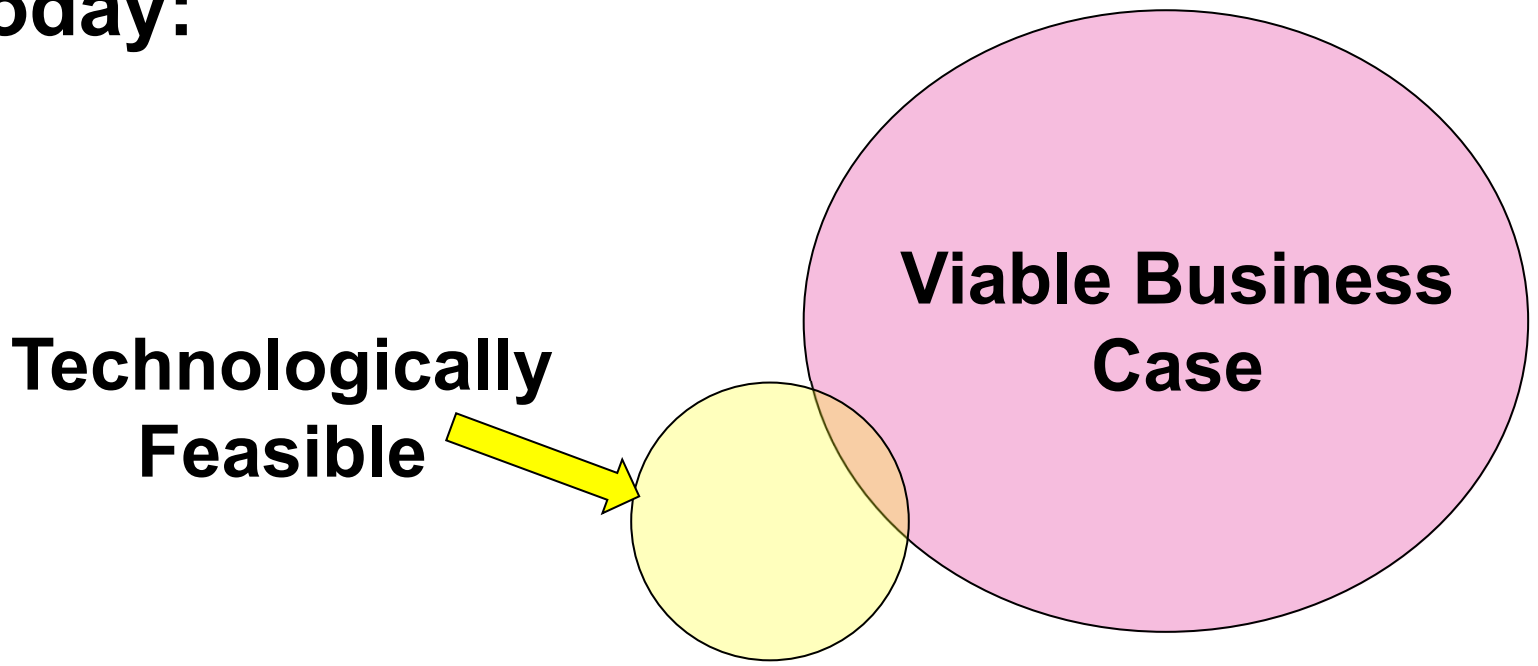
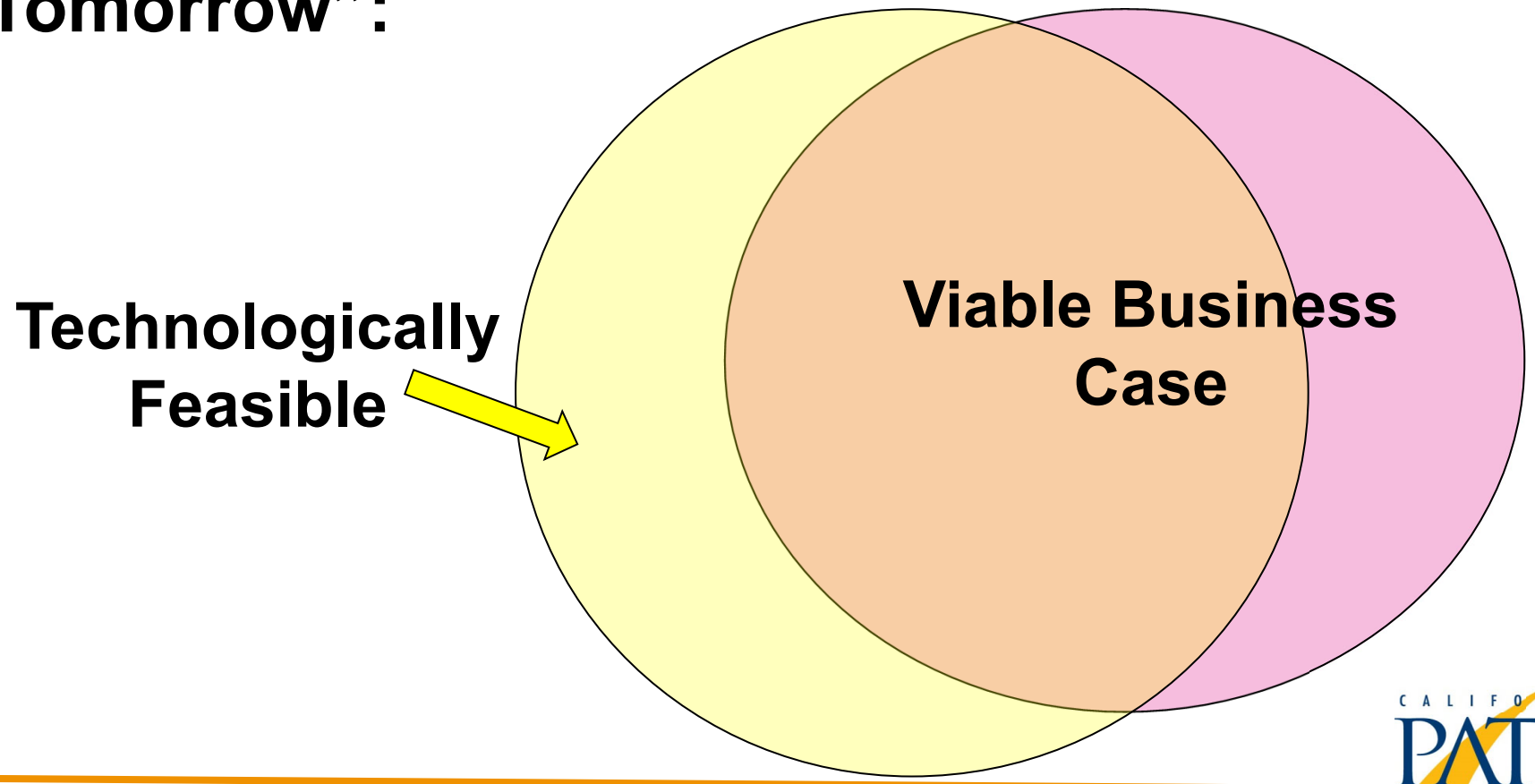
Where Can CAD Systems Operate?

Today:



Where Can CAD Systems Operate?

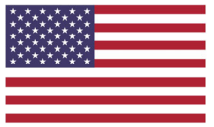
"Tomorrow":



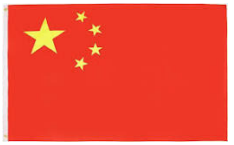
International CAD Contrasts

- Transport policy driven
- Strong public investments
- Automotive OEM priority
- Strong safety regulations

- Priorities differ by ministry
- Emphasis on lower levels of automation, auto OEMs
- Very cautious about safety
- Primitive L4 for rural access



- Private investment driven
- IT industry priority
- Level 4 automation emphasis
- No national regulations



- Industrial policy driven
- Level 4 automation emphasis
- No safety culture

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Learning from Early Driverless Deployments

- Testing by drivers → driverless testing → driverless deployments (California permit sequence)
- Distinct niche applications meet distinct challenges
- Interactions with emergency responders
- Infinite number and variety of “corner cases”
- Remote human support via wireless communication
- Diverse public perceptions
- Disregard examples from China
- Lessons for regulations

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Public Road Testing in California

- **Essential for development → start with test drivers**
  - **Driver qualifications**
  - **Driver training**
  - **Comprehensive reporting on mileage, crashes, driver interventions, near misses, minimal risk maneuvers…**
- **Driverless testing (with remote human support)**
  - **Authorize based on data from drivered testing**
  - **Essential for identifying problems that drivers covered**
  - **Staged authorization of fleet size increases**
  - **Comprehensive reporting continuing**

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Full Deployment on Public Roads

- Approve for specific application and operating conditions based on successful test results
  - Consider ongoing updates that will change behavior and may create new problems
- Engage with local stakeholders regarding potential restrictions on CAD usage
- Inform ADS developers/operators about incidents and road infrastructure changes
- Continue data collection and reporting to monitor effects of updates and unexpected outcomes

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Each Niche Application is Different

- **No "general" automated driving system**
  - **Urban (which city?), suburban or rural driving?**
  - **Motorways or general surface streets?**
  - **Long-haul, middle mile or local delivery trucking?**
  - **Ride-hailing or fixed-route passenger service?**
- **Extensive learning needed to expand or change scope of service and/or ODD**
  - **Scalability challenge for developers**
  - **Limits rate of market expansion**
  - **Approval processes need to recognize this**

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Emergency Responder Interactions

- Major issues in San Francisco with police, fire and ambulance services
- Data largely anecdotal and incomplete
- ADS not recognizing caution tapes, fire hoses, firefighting scenes
- ADS (unintentionally) blocking access
- City and ADS developer coordination
  - Companies authorizing emergency responders to drive their ADS vehicles
  - City providing real-time incident location data to ADS companies ('no-go' blocks)

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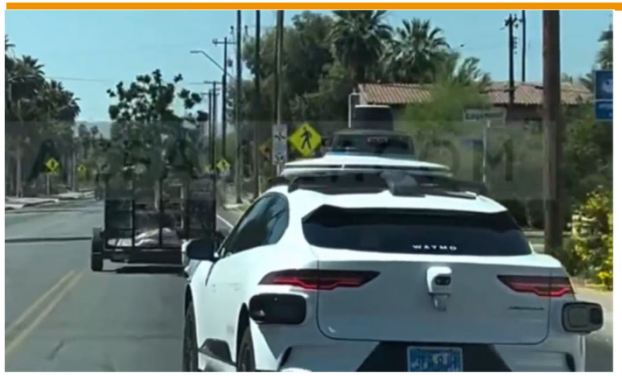
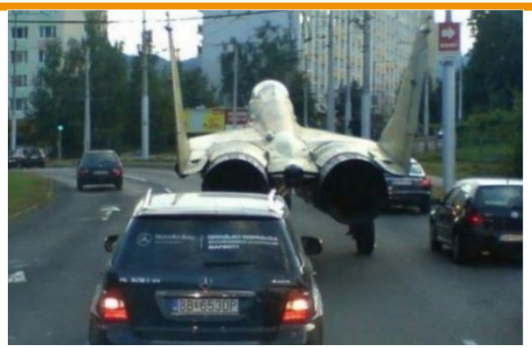
Infinite Variety of “Corner Cases”





- **Can never compile “complete” collection for ADS training or assessment**
  - **Comprehensive type approval testing of corner cases is not feasible**
  - **Cannot “prove” ability of ADS to manage them safely**
- **Resiliency of response to new conditions will be critical to assessing real-world ADS safety**

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Remote Human Support

- **All Level 4 systems rely on remote human support**
  - **Remote assistance to understand edge case scenarios, provide Go / NoGo advice, define waypoints**
  - **Remote driving (but with dubious safety)**
  - **Significant operating cost burden**
- **Requires wireless communication (currently 4G or 5G cellular), even for vehicles that do not use CAD**
  - **Implications of cellular service latencies and disruptions (natural disasters, terrorist events, large special events)?**

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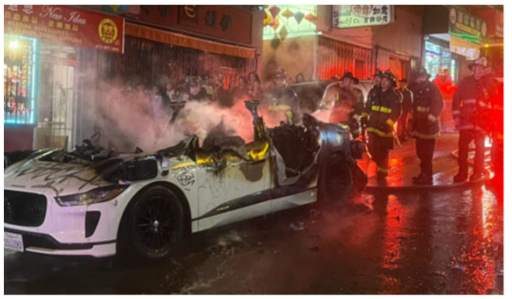
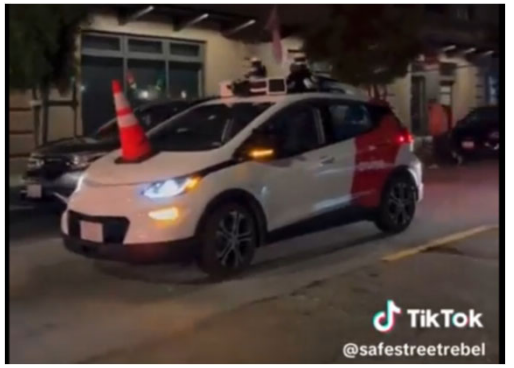
Diverse Public Perceptions

- General concerns about ADS technology – Forbes survey reported Feb. 2024:
  - 25% very untrusting + 21% somewhat untrusting
  - 22% somewhat trusting + 12% very trusting
- Willingness to pay $5K more for “self-driving” car?
  - 29% very or somewhat willing
  - 52% very or somewhat unwilling
- Labor unions sponsoring state legislation to require a driver in all heavy vehicles with ADS
- More open information sharing needed to earn public trust





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Chinese Company ADS Developments

- Strong national push for L4 ADS to enhance industry competitiveness (for industrial policy, not transport)
- Frequent media reports on urban ride-hailing in China
- No meaningful safety regulations
- U.S. ADS industry lobbyists cite “China threat” to fight against U.S. safety regulations
- Multiple Chinese companies testing ADS in California
  - Lack of safety culture and safety cases
  - Poor attention to regulatory reporting requirements
- Not a good model to emulate

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Regulating CAD Safety

- **Hybrid approach needed for CAD driving behavior – neither pure type approval nor self-certification of compliance with specific standards**
  - **Diversity of applications, ODDs and edge cases makes scenario-based type approval testing questionable**
- **Emphasize critical reviews of Safety Case and Safety Management System to assess readiness for public deployment**
- **Good start with EU 2022/1426 of 5 August 2022**
  - **Narrowed to specific early use cases**

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