Implementing Packet Dynamic Awareness in Argus

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Guha, Kidwell, Barthur, Cleveland, Gerth and Bullard: A Streaming Statistical Algorithm for Detection of SSH Keystroke Packets in TCP Connection ICS-2011 - 12th INFORMS Computing Society, Monterey, pp. 73-91 ISBN 978-0-9843378-1-1 DOI 10.1287/ics.2011.0036

- New ideas are needed to improve computer network defense with regard to scalable attack attribution (AA) and advanced situational understanding (SU)
- Packet Dynamics (PD) are a new set of connection-level variables based on time, including inter-packet, protocol state transition, latency and session arrival times.
- Adding packet dynamic metrics to traditional monitoring strategies, enhances the sensitivity and accuracy of anomaly detection for a number of issues.
- We will discuss its implementation in Argus, and how we use Packet Dynamics in near-realtime cyber-situational awareness systems.

Packet Dynamics

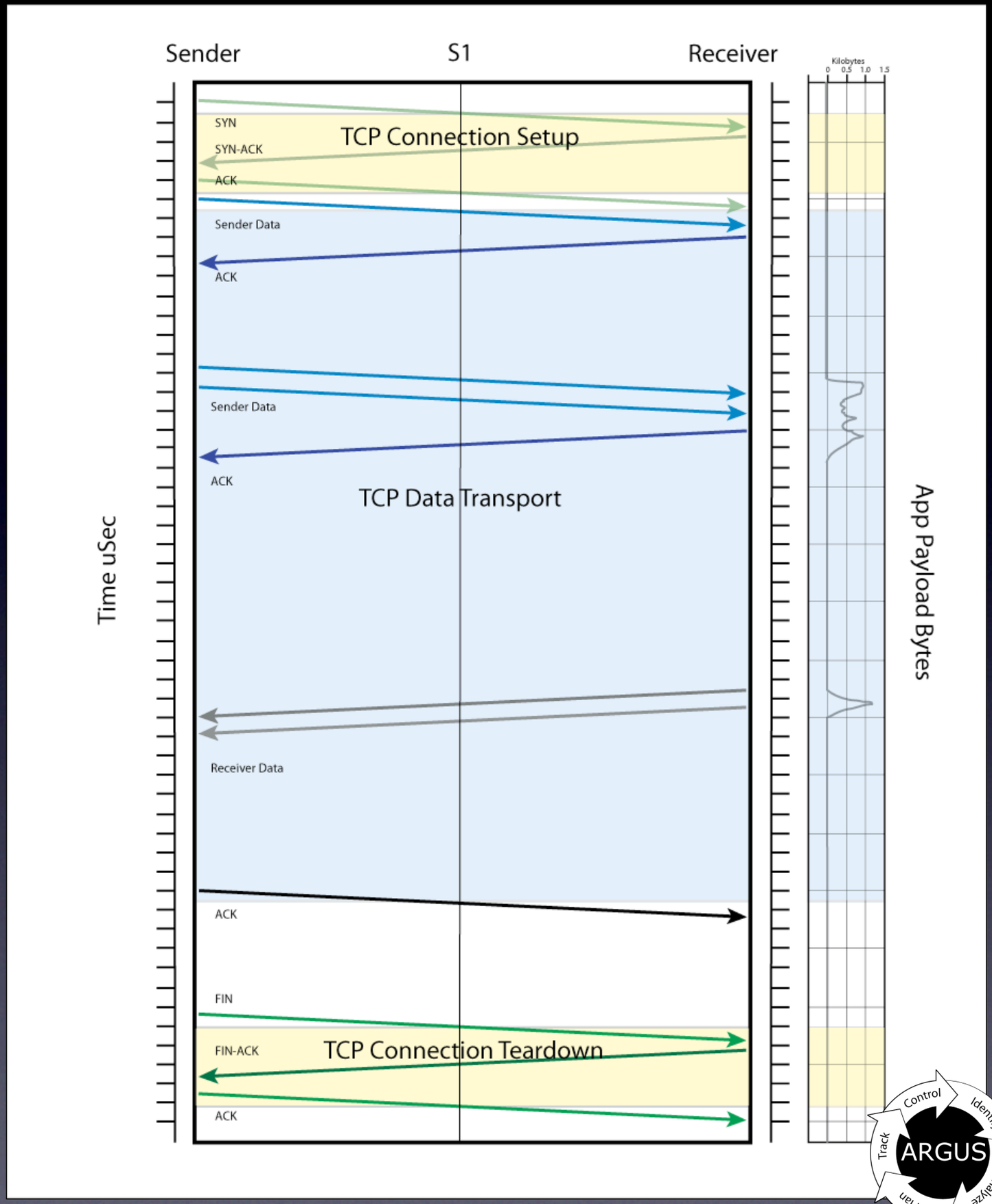
- Dynamics generally refer to property change over time
- Packet dynamics (PD) have been described as connection-level properties such as packet ordering, loss and delay, and how they change over time. V. Paxon, End-to-end internet packet dynamics. IEEE/ACM Trans. Netw. 7, 3 (June 1999).
- Packet dynamics include many properties such as inter-packet arrival times, packet burst behavior, state transition times.
- New understanding of packet dynamics can provide awareness for network path assurance, man-in-the-middle detection, stepping stone detection, replay and attribution.

TCP Replay Attacks

- Predicting a machines next TCP base sequence number, enables elementary, trusted source attacks.
    - Attack a remote target, such as a border router, by simply streaming a hand crafted TCP connection to the target machine, masquerading as an internal trusted source. Don't have to see the targets data stream.
    - Very common and successful strategy against older TCP/IP stacks
    - Detection is very difficult with simple uni-directional flow data
- Awareness of the packet dynamics of the attacking TCP connection, can lead to simple and immediate detection.

TCP Normal Connection

- State Development Time
  - TCP Setup Time
  - Data Presentation Delay
  - Data Transport Time
  - TCP Teardown Time
- Host Dynamics
  - Data Burst Rate
  - Data Ack Delay
  - Host Processing Time
- Network Dynamics
  - One-way Delay (shaping)
  - Round Trip Time
  - Loss Rate

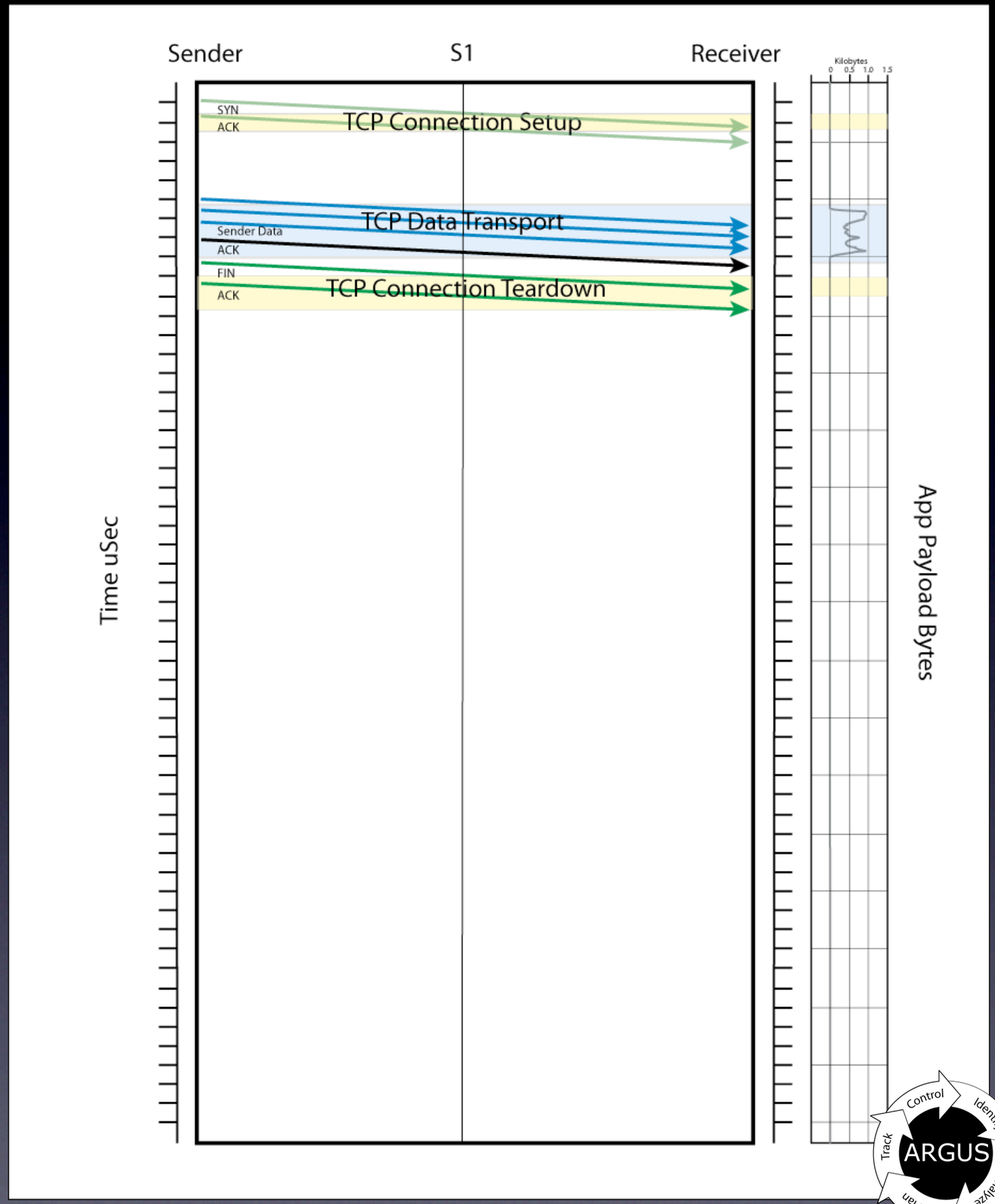


TCP Replay Sender

- Attacker generally sends entire TCP connection all at once.

  Sophisticated attempts inject pseudo packet delay

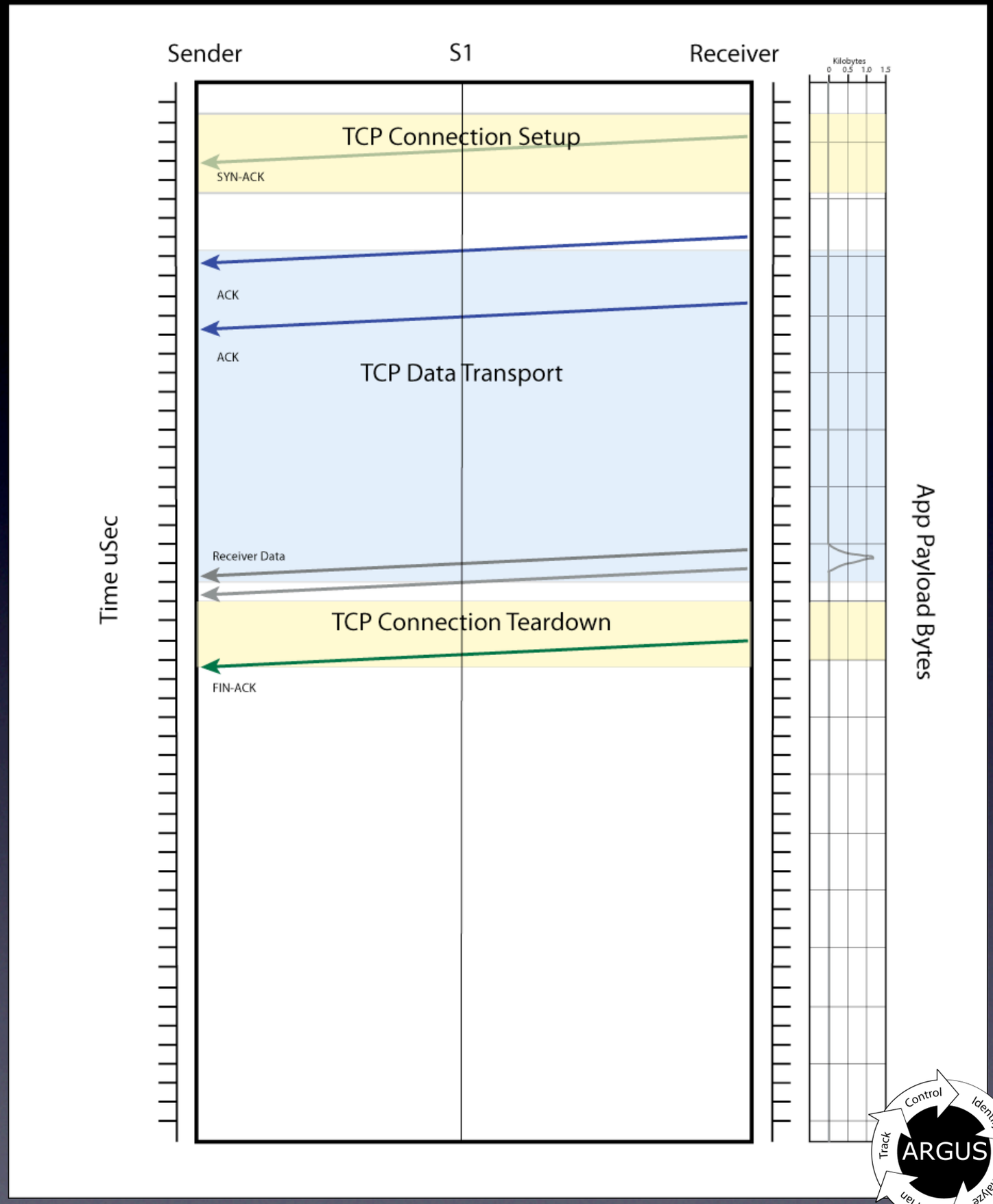
- State dynamics ignored
  - RTT Insensitive
    - TCP Setup Time
    - Data Transport Time
    - TCP Teardown Time



TCP Replay Receiver

- Receiver responds in a conventional manner

  Dynamics, however, shifted toward being driven by processing delay, rather than network delay.



TCP Replay Connection

- Overall connection is contracted

  All data transport appears to be at line rate

- Protocol state violated

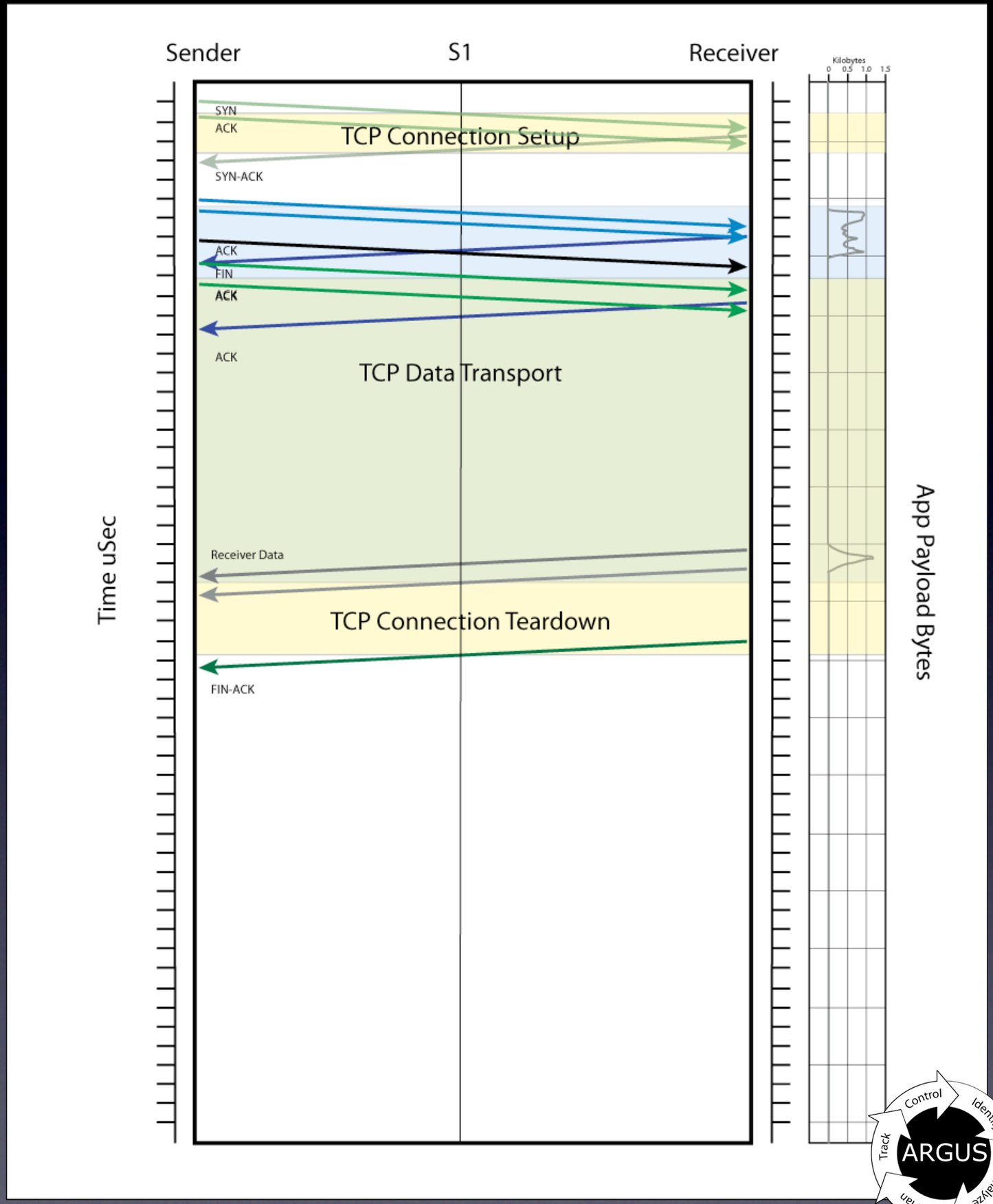
  Response seen before Request

  ACKs before Data

  Impossible TCP Setup Time

  Packets out of phase but not out of order

  Massive TCP Teardown Time



Flow Data Attributes

- Bi-Directional Stateful Flow Monitoring
  - TCP Protocol State Durations
    - TCP connection setup duration
      - SYN -> SYN_ACK time
      - SYN_ACK -> ACK time (negative value !!!!!)
    - TCP connection teardown duration
      - FIN -> FIN_ACK time
      - FIN -> RESET time
    - TCP window performance
      - Correlating data packets with ACKs
- Inter-packet arrival times
  - GeoSpatial and NetSpatial correlation

SSH Keystroke Detection

- Discriminating between machine and human driven network activity is very important
  - Threat model is different between automation and human interactive sessions
  - Specific behavioral indicators of security relevant conditions
- Discerning behavior in encrypted streams restricts approach to behavioral strategies

Algorithm Goals

- Detect SSH client keystroke packets in arbitrary TCP connections
  - Detect SSH flows in any connection, on any port.
    - No packet content inspection, header only
- Deployable in production networks
- Suitable for near realtime detection and reporting

Algorithm Details

SSH Protocol Rules

I. SSH Startup Handshake Detection (22 pkts)
II. SSH Packet Size (mod 4 = 0)

Packet Dynamic Rules

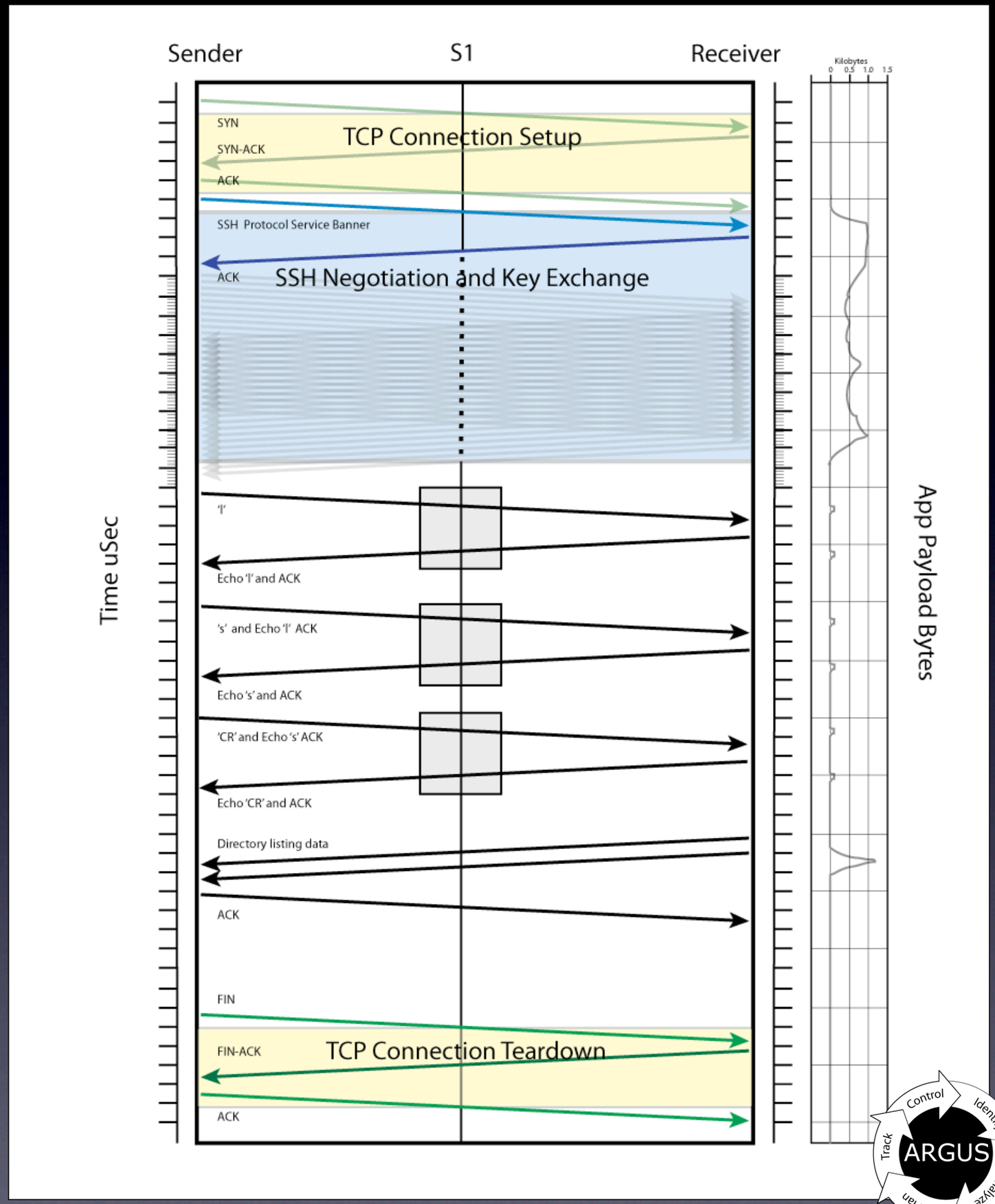
1. Minimum client data size (48 bytes)
2. Maximum client data size (128 bytes)
3. Maximum server echo gap size (3 pkts)
4. Minimum server echo data size (24 bytes)
5. Maximum server echo data size (256 bytes)
6. Minimum client inter-arrival time (50 mSec)
7. Maximum absolute log inter-arrival ratio (1.122)
8. Maximum previous-current gap (3 pkts)

Classification Variables

- Whether a packet is from the client or server
- Whether there are more than 22 packets in the connection
- Whether there are client packets after packet 22 or not
- Data size for client packets
- Data size for server packets
- The number of packets between a client packet with data and the next acknowledging server packet with data
- Inter-arrival time of two successive client packets with data
- Inter-arrival time of two successive echoing server packets
- The ratio of a client inter-arrival time and the inter-arrival time of the corresponding echoing server packets
- The number of packets between two successive client packets with data.

SSH Keystroke Detection

- All data packets of the correct size (% 4 = 0)
- SSH protocol in data transfer state (> 22 pkts)
- Previous packet arrival within tolerances (human typing).
- Bi-directional sequential data packet sizes within tolerances
- Data and Echo Packets RTT within tolerances



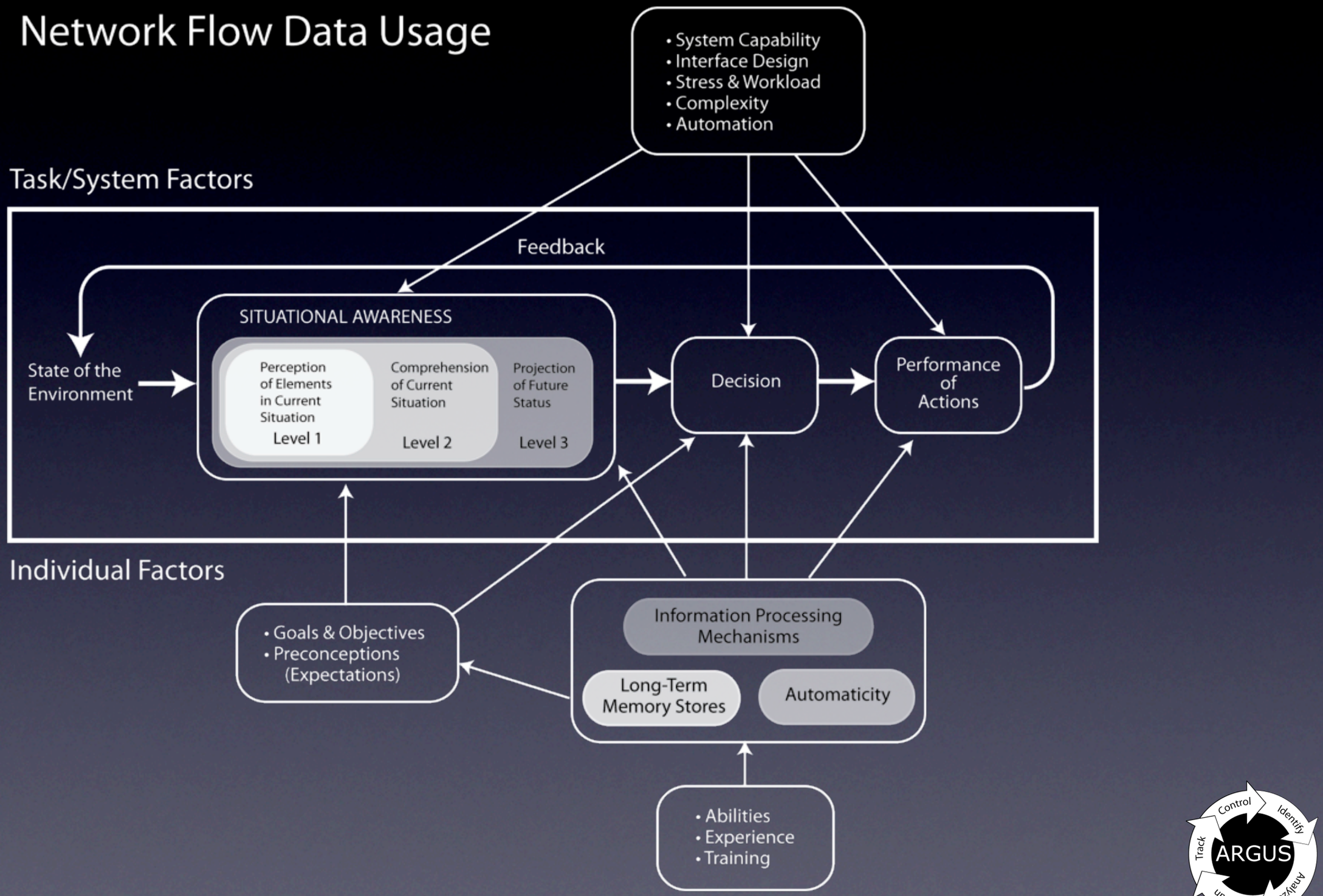
Keystroke Detected

Reporting Metrics

- Argus Behavioral DSR
  - Algorithm Family Identifier (DSR subtype 8 bits)
  - Algorithm Identifier (DSR qualifier 8 bits)
  - Algorithm Specific Metrics (< 32K bytes)
- Presence of the DSR indicates that the algorithm was applied to the flow during the status interval.
- Presence of algorithm metrics indicate that there were analytic results during the status interval
- Algorithm generates keystroke counts for both directions
- DSR meets all Argus DSR operational requirements
  - ra keyword " nstroke " (number of keystrokes)
  - printable, graphable, filterable, aggregatable, etc.....

Model of Situational Awareness in Dynamic Decision Making

Network Flow Data Usage



Situational Awareness

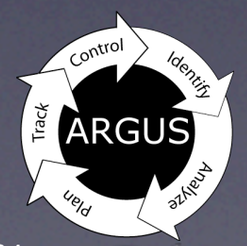
Level 1 SA - Perception

- The perception of elements in the environment within a volume of time and space
- Involves timely sensing, data generation, distribution, collection, combination, filtering, enhancement, processing, storage, retention and access.

Level 2 SA - Comprehension

- Understanding significance of perceived elements in relation to relevant goals and objectives.
- Involves integration, correlation, knowledge generation.

Level 3 SA - Projection of Future Status



Endsley, M. R. (1995b). Toward a theory of situation awareness in dynamic systems. Human Factors 37(1), 32-64.

Alarming Conditions

- Keystrokes are expected in most ssh connections
  - For many SSH connections the absence of keystrokes is the actionable condition
  - Keystrokes should appear in various phases of an SSH.
    - Human initiated connections should have keystrokes at the beginning and end of an SSH connection.
    - Absence of keystrokes at closure, may indicate timeout conditions.
  - Historical behavioral baselining will identify connections where keystroke monitoring is helpful
- Almost always (> 99.9%) , the originator of the SSH connection will be doing the typing
  - Anytime the destination originates keystrokes, you probably have a really serious problem !!!!!

Live Demonstration

from Presentation Laptop

ra and ratop screens with me ssh'ing to the qosient.com

hopefully we can have that going on a separate

projector during the talk. need to tune the parameters

for end system sensing.