In Search of Cybernautics

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Progress in Information Technology

Microprocessor performance has increased by factor of 25,000 since 1971 (Intel 4004 to Pentium 120).

Rate of increase has been 52% per year.

Rate has accelerated to 58% over past 5 years.

Performance multiplies by 10 every 5 years.
The Two Cultures

We Know All about These

\[ f = ma \]

\[ L = \rho U \Gamma \]

\[ \rho \frac{\partial \mathbf{u}}{\partial t} + \rho \mathbf{u} \cdot \nabla \mathbf{u} + \nabla p = \mu \nabla^2 \mathbf{u} \]

But What about This One?

\[ C = B \log_2 \left[ 1 + \frac{S}{N} \right] \]
## Data Rates

(bps = bits per second)

<table>
<thead>
<tr>
<th>Device</th>
<th>Bandwidth</th>
<th>Data Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modem</td>
<td>4.2 MHz</td>
<td>28.8 Kbps</td>
</tr>
<tr>
<td>CD-ROM</td>
<td>140 MHz</td>
<td>5.6 Mbps</td>
</tr>
<tr>
<td>Ethernet</td>
<td>120 MHz</td>
<td>10.0 Mbps</td>
</tr>
<tr>
<td>Cable TV</td>
<td></td>
<td>33.6 Mbps</td>
</tr>
<tr>
<td>Hard Disc</td>
<td>32</td>
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</tr>
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<td>Video Card</td>
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</tr>
<tr>
<td>Human Eyes</td>
<td>400 MHz</td>
<td>10</td>
<td>4.00 Gbps</td>
</tr>
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</table>
Aviation Now

Air

Expert pilots
Manual controls
Multiple navaids
Waypoint navigation
See and avoid under VFR
Voice communication with ATC
No communication with other aircraft

Ground

Expert controllers
Radar and Mode S sensors
Voice communication with aircraft
GPS Navigation and Control Tests

University of Arizona

El Cuervo 2

Stanford University

Paul Montgomery’s Model Aircraft
Piper Dakota and Wide Area Augmentation System
Piper Dakota and Kinematic GNSS Landing System

NASA Ames Research Center

King Air Precision Landings with DGPS/INS
Stanford Model Aircraft Navigation and Control System
Model Aircraft Flight Path

950417 : flight1
FAA Wide Area Augmentation System

RNP Cat. I Availability Contours: FAA 18-WRS NSTB

[Map of the United States with RNP Cat. I availability contours and markers for various cities like Sea, Elko, Cas, Den, Colm, GB, Day, And, S.Ang, Grn, Gain, GFal, GFrik, Arc, Gal, Riv, OKC, and Ba.]

Latitude (deg.)
Longitude (deg.)

-130 -120 -110 -100 -90 -80 -70
20 25 30 35 40 45 50 55
Touch and Go Landings with WAAS
Stanford Kinematic GNSS Landing System
NASA Ames DGPS/INS System
Precision Approaches with DGPS Disabled at 200 ft

NASA King Air at Crows Landing, 22 Landings, 7/21/95
Aviation Future

Air

Automatic controls
GNSS/INS guidance
Free flight navigation
Inter-aircraft communication
Automatic collision and wake avoidance
Radio control reception for emergencies

Ground

GNS integrity assurance
Rules of the sky software
Expert pilots for emergencies
Fig. 1-1 Distribution of passenger trip lengths on scheduled domestic airline flights in the United States, November 1980. (Civil Aeronautics Board [17].)
EFFECTIVE SPEED
Tucson through DFW Hub

Miles per Hour

Direct Miles

0 500 1000 1500 2000 2500

0 100 200 300 400
Empty Weight vs Max Takeoff Weight

\[ W_{\text{empty}} = 0.656 \times W_{\text{maxto}}^{0.988} \]
Conclusions

The information age is real and has produced machines able to process data as fast as humans and handle quantitative data much better.

The Global Positioning System allows vehicles to determine location, velocity, and attitude.

Digital telecommunications allow vehicles to communicate their states and plans among each other.

The rate gap between central processing and telecommunications will persist, so the brains of a transportation system will be aboard the vehicles.

Synthetic intelligence and telecommunications are cheap!

All this bodes well for personal aviation.