GLOBAL NAVIGATION SYSTEM

SENSOR APPROACH

(GNSSA) MODULE

OVERVIEW
NovAtel: Who are we?

- Canadian Corporation, located in Calgary, Alberta, Canada
- Established 1983 - initially Telecommunications now 100% high-end GPS
- Initial public offering in 1997 (NASDAQ: NGPS)
- 1999 revenues $24.2 m Cdn, 100 people, 46,000 sq. ft HQ
- BAE SYSTEMS Canada majority shareholder (58%)
NovAtel: Our Organization

- OEM
- Aviation
- Custom Products Group
- Research and Development
- Marketing and Sales
- Customer Service and Support

BAE SYSTEMS
NovAtel GPS Technologies
Innovative, Proprietary Technology

- High-Density VLSI / DSP Section
- Narrow Correlator
- RT-20
- MEDLL / WAAS
- MET Software
- MiLLennium / RT-2
- MiLLennium-WAAS / DL Series / GPS GLONASS
- OEM4/WAAS RFI & SFD
- GPS- 600 Antenna INS/GPS

Years:
- 1991
- 1992
- 1993
- 1994
- 1995
- 1996
- 1997
- 1998
- 1999
- 2000
GNSSA Program

- Global Navigation System Sensor Approach (GNSSA) module
- Joint Program between BAE Systems Canada (BSC) & NovAtel
- High integrity GPS landing receiver, designed to meet latest DO-229B MOPS & TSO C-145, LAAS CAT I/II/IIIb
- Integrated in Honeywell airborne FMS products
- Designed for integration into all Local Area Augmentation System (LAAS) ground stations
GNSSA Program

- NovAtel - L1/L1 dual RF front-end & MINOS4 DSP ASIC qualification
- BSC - Receiver integration, Digital, Interface ASIC, DO-178B Level A Software
- Beta receivers scheduled for Spring 2000
- Certification scheduled for September 2000
- Market split: NovAtel address ground
  BSC address air & Honeywell ground
CMA 4024 GNSSA Module

- Fault Monitor Connector
- L1 Antenna Inputs
- External Interface Connector
- A/D
- MINOS-4 ASIC
- CIA ASIC
- SRAM
- K6-2 CPU
- TCXO
- External Oscillator Input
- FEPROM
GNSSA Pre-production Model
GNSSA Program
CMA 4024 GNSSA Module - Specifications

ACCURACY (Without Selective Availability)
Horizontal Position  22.5 meters, 95% S/A off
Altitude       30 meters, 95% S/A off
Velocity       0.05 knot, 95% S/A off
Track Angle    0.5° (V > 120)
Vertical Velocity 200 feet per minute
Time           2 microseconds
GPS Measurement Accuracy  0.15 meters

ACQUISITION TIMES
Initialized First Fix  105 sec. Max; 95% confidence
No Initialization    10 min. worst case; 3 min. nominal
Power Drop-out < 10 seconds  5 sec. typical
Satellite Re-acquisition  5 sec. typical

PHYSICAL / ENVIRONMENTAL
Size           6.5” x 4.5” x .6”
Weight         < .7 lbs
Temperature Range -55 to + 85 ° C
Altitude Range Between 15,000 and 60,000 ft
## GNSSA Program

### CMA 4024 GNSSA Module - Specs (continued)

#### ELECTRICAL POWER

<table>
<thead>
<tr>
<th>Operating Power</th>
<th>12.5 Watts max.</th>
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</thead>
<tbody>
<tr>
<td>Input Power</td>
<td></td>
</tr>
<tr>
<td>+3.3 ± .25 VDC</td>
<td>2000 mA 6.6W</td>
</tr>
<tr>
<td>+5 ± .25 VDC</td>
<td>300 mA 1.5W</td>
</tr>
<tr>
<td>+14 + 1.5 - 0.5 VDC</td>
<td>200 mA 2.8W</td>
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<tr>
<td>-14 + 1.5 - 0.5 VDC</td>
<td>80 mA 1.1W</td>
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<tr>
<td>TOTAL</td>
<td>12.0W</td>
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</table>

#### RELIABILITY

| Operational Hours MTBF | 72,000 hours |

#### SENSITIVITY

<table>
<thead>
<tr>
<th>Acquisition Sensitivity</th>
<th>-134.5 dBm 100K Sky Noise</th>
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</thead>
<tbody>
<tr>
<td>Tracking Sensitivity</td>
<td>3 dB less C/No than acquisition</td>
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#### INTERFERENCE

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<thead>
<tr>
<th>In-band CW Rejection</th>
<th>RTCA/DO-229B Appendix C</th>
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<tbody>
<tr>
<td>Out-of-band Rejection</td>
<td>RTCA/DO-229B Appendix C</td>
</tr>
<tr>
<td>+30 dB min band</td>
<td></td>
</tr>
<tr>
<td>Burn-out Protection</td>
<td>+20 dBm out of band</td>
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</table>
## GNSSA Program
### CMA 4024 GNSSA Module - Specs (continued)

<table>
<thead>
<tr>
<th>INTERFACES</th>
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<tbody>
<tr>
<td>Inputs</td>
<td>9 ARINC 429, 2 RS-232, 2 RS-422</td>
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<tr>
<td>Outputs</td>
<td>5 ARINC 429, 2 RS-232, 2 RS-422</td>
</tr>
<tr>
<td></td>
<td>2 28V valid discrete</td>
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<tr>
<td></td>
<td>3 1-Hz time marks</td>
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<thead>
<tr>
<th>SOFTWARE</th>
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<tbody>
<tr>
<td>Language</td>
<td>Ada</td>
</tr>
<tr>
<td>Level</td>
<td>DO-178B level A development level B certification</td>
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<tr>
<td>Processor</td>
<td>64-bit K6-2</td>
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<table>
<thead>
<tr>
<th>BITE</th>
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<tbody>
<tr>
<td>Continuous coverage</td>
<td>&gt; 95% fault decision</td>
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<table>
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<tr>
<th>CONFORMITY</th>
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<tr>
<td>ARINC 429-12, ARINC</td>
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<tr>
<td>743A, DO-160D,</td>
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<td>DO-217 (optional),</td>
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<td>DO-178B, DO-229,</td>
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<tr>
<td>DO-245, TSO-C129A,</td>
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<tr>
<td>TSO-C145</td>
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GNSSA Block Diagram

CPU INTERFACE ASIC

CIA PRIMARY

L1 RF

A/D

L1 RF

A/D

XTAL
32.768kHz

TCXO
40 MHz

TIME MARK
DRIVER/RECEIVER

CPU INTERFACE ASIC
CIA PRIMARY

MINOS-4
DSP
ASIC

CPU
PENTIUM K6-2

FEPROM

FEPROM

SRAM

SRAM

CIA
SCDNY 1

ARINC 101
LINE RECEIVER

ARINC O/P
LINE DRIVER

SERIAL I/O

DISCREDES I/O

UARTS
INTERFACES

A/D CONVERTER
D/A CONVERTER

FAULT
MONITOR
PROCESSOR

EEPROM /
FEPROM

BACKUP P/S

Fault Monitor Processor

A/D Converter

Discretes I/O

UARTs Interfaces

Serial I/O

ARINC O/P Line Driver

ARINC 101 Line Receiver
Dual L1 / L1 RF-Deck

- Two independent RF-channels
  - independent antenna feeds
  - independent digital outputs
- Single stage down conversion to 70MHz
  - minimizes in-band intermodulation & interference
Dual L1 / L1 RF-Deck

- IF amplification stage has 45dB AGC range
  - covers full GPS signal strength variation
  - accommodates DO-229B RF interference
- 3-bit sampling at 40 MHz
  - practical optimum for RFI resistance
  - superior RFI resistance
Dual L1 / L1 RF-Deck

VOLT SENS AND POWER CONTROL (2X EACH)

ANT. PWR. CONTROL

ANT. POWER

SYNT

70 Mhz DISCRETE

AGC

70 Mhz SAW

MATCH

A/D

3 BITS

MATCH

A/D

3 BITS

MATCH

VARF

VARF

1505.5 Mhz

1504.5 Mhz

10 MHz TCXO

BUFF/ FREQ. CONV.

40 Mhz

MINOS CLK

EXT. 10 MHz OSC.

10 MHz

BITE

VOLT SENS AND POWER CONTROL (2X EACH)

ANT. PWR. CONTROL

ANT. POWER

SYNT

70 Mhz DISCRETE

AGC

70 Mhz SAW

MATCH

A/D

3 BITS

MATCH

A/D

3 BITS

MATCH

VARF

VARF

1505.5 Mhz

1504.5 Mhz

10 MHz TCXO

BUFF/ FREQ. CONV.

40 Mhz

MINOS CLK

EXT. 10 MHz OSC.
MINOS-4 DSP ASIC

- 24 correlator channels, each correlator channel comprises:
  - Early-Late I and Q channels
  - Prompt I and Q channels
  - Large DCO range accommodates GLONASS spectrum

- GPS C/A and P codes (not P(Y))
- GLONASS C/A and P codes
- Narrow Correlation to 1/20th chip spacing
• Two independent data inputs
• On-the-fly configuration of correlator channels
  – selectable input channel
  – selectable GPS/GLONASS C/A or P code
• Hardware sky search
• Hardware bit histogram
L1/L1 GPS Receiver

MINOS4 Block Diagram

Channel
1 & 2
3 & 4
5 & 6
7 & 8
9 & 10
11 & 12
13 & 14
15 & 16
17 & 18
19 & 20
21 & 22
23 & 24

A Sample Conditioner
B Sample Conditioner

RF A AToD
RF B AToD

Charge Pump for AGC
Timers
Control
Input & Output
CPU

AGC
1PPS

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ARINC 429 Transmitters

- Five independently buffered outputs (out of a maximum of 8 available)
- Each output can be driven at either high speed (100 kHz bit rate) or low speed (12.5 kHz bit rate)
- Each output is fully monitored with an independent receiver read-back
- Same proven design as GNSSU
ARINC 429 Receivers

- Nine ARINC 429 input buses
- Each input has the capability to receive data @ either high speed (100 kHz bit rate) or low speed (12.5 kHz bit rate)
- Data rate automatically detected by software
- Same proven design as GNSSU
Time Mark Driver / Read-back

- Three independently buffered outputs
- Outputs meet EIA Standard RS-422 for voltage levels & impedance
- Each output is fully monitored with an independent receiver read-back
Discrete Inputs

- Eleven Discrete Inputs
- Standard Open/Ground with diode isolation
- Proven design
- Power Down Interrupt (PDI) discrete for advance warning of power failure, uses TTL level inputs
Discrete Outputs

- Two Discrete Outputs are available
- Each output has the capability to sink 280 mA through a resistive load
- Each output is short circuits protected
- Each output is fully monitored
**RS-232 input/output**

- Two independent RS-232 output and input ports
  - Each output meets the EIA Standard RS-232 for voltage levels and impedance requirements.
  - Baud rate is programmable from 9600 to 115200 bits per seconds
  - Parity = none
  - Start bits = one
  - Stop bits = one
  - Data bits = eight

- Same proven design as GNSS Module
RS-422 input/output

- Two independent RS-422 output and input ports
  - Each output meets the EIA Standard RS-422 for voltage levels and impedance requirements.
  - Baud rate is programmable from 4800 to 1.2M bits per seconds
  - Parity = none
  - Start bits = one
  - Stop bits = one
  - Data bits = eight
- Same proven design as GNSS Module
Fault Monitor Processor

- Similar hardware to that of the GNSSA
- Inputs:
  - A/D samples from GNSSA and 40MHz clock signal
  - ARINC and RS-232/422 outputs from GNSSA
  - Power
- 2 lines send health status between the two processors. Lines are frequency modulated to prevent stuck HI or LOW. In case of discrepancies between GNSSA and Fault Monitor, Fault Monitor prevents data output.
- Designed for future plug-in update
Reliability

- GNSSA MTBF = 72,000 operating hours
- Reliability prediction based on MIL-HDBK-217F:
  - using adjustment factors for:
    - field experience (GNSSU)
    - engineering judgment
    - test data
    - manufacturer data
  - environmental conditions:
    - Aircraft uninhabited Cargo (AUC) @ 40° C
- Component Stress Analysis for high temperature
LAAS Receiver

- US FAA LAAS Ground Facility (LGF) specification requires:
  - Signal Quality Monitor (SQM) - RTCA SC-159 WG 4A
  - Tracking 18 satellites, including up to 4 GEOs, pseudolites also possible
  - Antenna performance implies two element Multipath Limiting Antenna (MLA)
  - MLA requires dual L1 RF receiver inputs
LAAS Receiver

- Signal Quality Monitor (SQM) requires:
  - Narrow Correlator ® tracking technology
  - Multiple correlators, at least 7 per channel
- Multipath Limiting Antenna (MLA) requires:
  - Dual RF inputs
  - Spare tracking channels for transition of mid-elevation satellites between 2 elements
LAAS Receiver

- NovAtel/BSC LAAS Receiver:
  - Meets LGF specification requirements
  - SQM function uses dual MINOS4 DSP – up to 10 correlators per channel
  - Tracks 18 GPS/GEOs with 6 dedicated transition & BITE channels
  - Dual RF for MLA antenna inputs
NovAtel/BSC would like to establish partnership

To work with LAAS system supplier:

➢ To verify LAAS receiver requirements
➢ Each supplier may need custom solutions
➢ To establish long-term business relationships
Summary

- NovAtel/BSC GNSSA development underway
- High integrity airborne version available soon for evaluation
- LAAS receiver requirements still evolving
- Significant receiver engineering required
- Risk-sharing partnerships needed to address LAAS market opportunity