AutoNaut Sea Trials - March 2019

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This document summarizes the sea trials that took place from the 6th to the 8th of March at Borsa.

Successfully tested communication means

L1 Iridium housekeeping

During the whole time the vehicle was in the water, the CR6 was configured to monitor the whole system (battery voltage, load current, solar panel power, communication with sensors). Iridium was configured to send a "housekeeping"message with a frequency of 30 minutes. The same behavior will be adopted once the AutoNaut will be deployed for longer missions, except for the frequency, which will likely be 1-2 messages per day. Also, the CR6 checks with the same frequency for inbox received Iridium messages. In the final implementation, reading and sending messages will be shifted by 12hs. Better solutions could be discussed.
At the moment, a housekeeping message has the following format:
$H,date,time,lat,long,cog,sog,power_settings
This will surely be extended with the battery voltage.
Note that this message is not meant to be dispatched in case of emergency/failure. In this latter case, instead, I have implemented a different message format that indicates the type of failure, appended to the housekeeping message. I have defined a set of conditions that are considered as emergency", like L2 or a GPS not responding for 30 minutes. The software checks for emergencies at every iteration. When an emergency is detected a message is built and dispatched immediately via Iridium, without waiting the next housekeeping message send time. The third type of message is named ACK: it is sent to the operator whenever the CR6 receives a new power settings instruction via Iridium. Example: say we need to turn on the VHF radio, which is off by default when the AutoNaut is in the ocean; I sent a message to the AutoNaut with a new combination of power settings, enabling Iridium; if the configuration is correctly applied, an ACK message is built with the new settings and sent back to

the operator, confirming the applications of the new settings. Below the housekeeping load of messages I received from the AutoNaut:

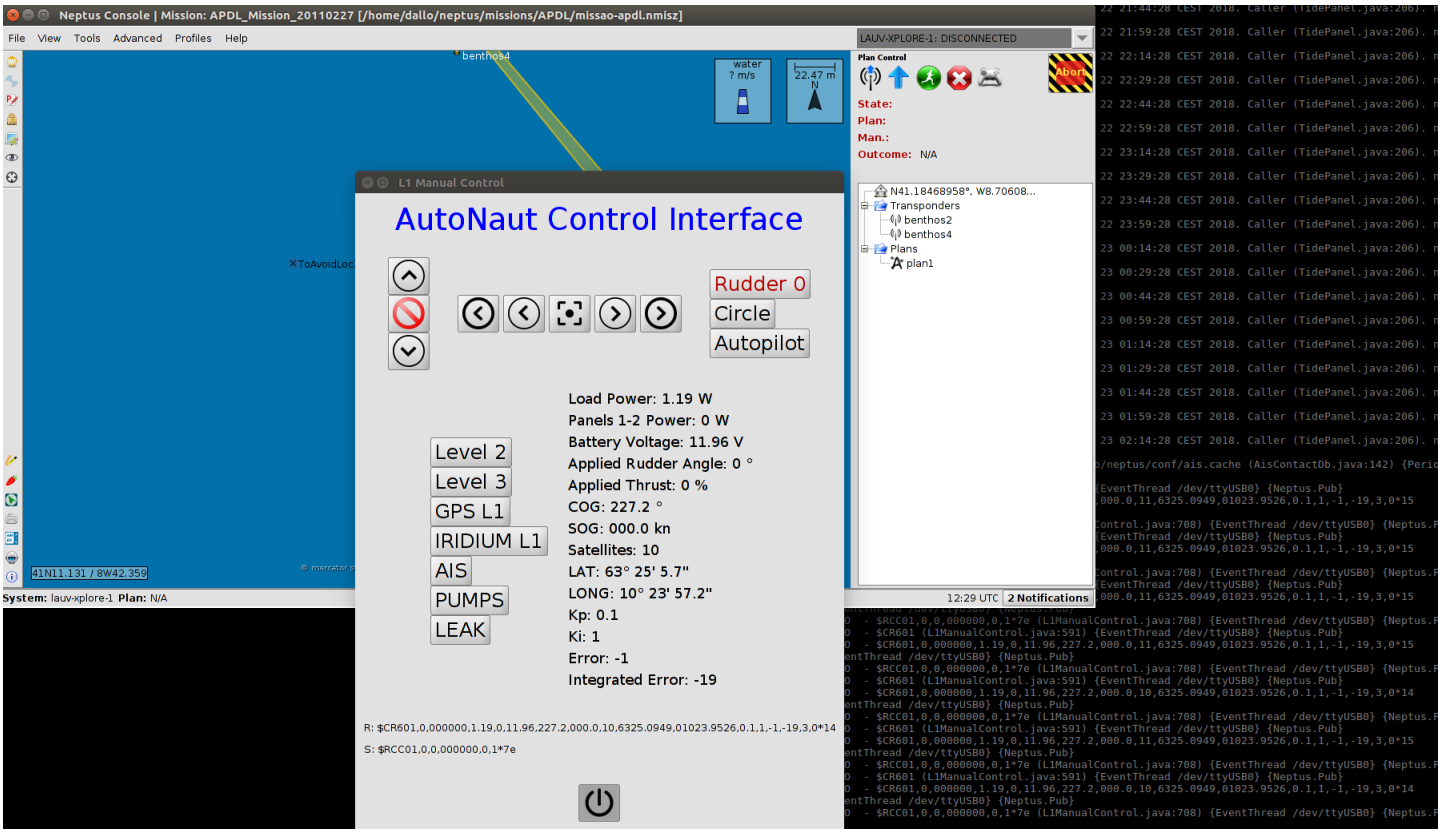
No payload"messages are triggered whenever the receiver checks the inbox and does not

Date Time (UTC)	Device	Direction	Payload	Length (Bytes)	Credits Used
08/Mar/2019 15:34:44	RockBLOCK 13614	MO	H,080319,153434,6319.9589,01004.2374,338.3,000....	56	2
08/Mar/2019 15:04:34	RockBLOCK 13614	MO	[No payload]	0	1
08/Mar/2019 15:04:25	RockBLOCK 13614	MO	H,080319,150420,6320.1229,01004.7820,245.0,000....	56	2
08/Mar/2019 14:34:16	RockBLOCK 13614	MO	H,080319,143412,6320.3593,01005.0270,320.9,000....	56	2
08/Mar/2019 14:04:11	RockBLOCK 13614	MO	[No payload]	0	1
08/Mar/2019 14:04:04	RockBLOCK 13614	MO	H,080319,140352,6319.9014,01004.7608,249.2,002....	56	2
08/Mar/2019 13:33:48	RockBLOCK 13614	MO	H,080319,133345,6319.8541,01008.3121,300.2,001....	56	2
08/Mar/2019 13:03:42	RockBLOCK 13614	MO	[No payload]	0	1
08/Mar/2019 13:03:38	RockBLOCK 13614	MO	H,080319,130330,6319.6475,01007.4722,079.2,000....	56	2
08/Mar/2019 12:33:25	RockBLOCK 13614	MO	H,080319,123314,6320.0107,01006.0513,087.2,001....	56	2
08/Mar/2019 12:02:34	RockBLOCK 13614	MO	H,080319,120221,6319.9811,01005.0066,055.5,002....	56	2
08/Mar/2019 11:32:17	RockBLOCK 13614	MO	H,080319,113214,6319.7857,01004.6370,101.8,000....	56	2
08/Mar/2019 11:02:12	RockBLOCK 13614	MO	[No payload]	0	1
08/Mar/2019 11:02:06	RockBLOCK 13614	MO	H,080319,110203,6319.8188,01004.5078,277.1,000....	56	2
08/Mar/2019 10:31:59	RockBLOCK 13614	MO	H,080319,103153,6319.9592,01004.2374,000.0,000....	56	2
08/Mar/2019 10:01:50	RockBLOCK 13614	MO	[No payload]	0	1
08/Mar/2019 10:01:44	RockBLOCK 13614	MO	H,080319,100141,6319.9580,01004.2382,000.0,000....	56	2
08/Mar/2019 09:31:37	RockBLOCK 13614	MO	H,080319,093134,6319.9578,01004.2374,000.0,000....	56	2
07/Mar/2019 15:50:28	RockBLOCK 13614	MO	H,070319,155016,6319.9555,01004.2427,269.2,000....	56	2
07/Mar/2019 15:20:16	RockBLOCK 13614	MO	[No payload]	0	1

find any message. As I never sent a message to the AutoNaut, at every check a credit has been used.

OWL VHF radio

The OWL VHF radio has been tested. This is a reliable communication link that has been tested up to 100km range. We will not replicate the same experimental conditions, but we can rely on this link for operations in the fjord. Because of the mission design, last week we had a maximum distance of 4km between the ground radio and the onboard radio. In the next trials I plan to have longer missions, I will be able to extend the link and test the communication over longer distances. The OWL is used for manual control and direct monitoring of L1 in Neptus.



WiFi communication with L2

In February I have implemented a communication link that allows the transmission of the full UDP load of IMC-based messages over 3G/4G. This allows real-time monitoring and control of the mission in Neptus. The BeagleBone has direct access to internet through a 3G/4G modem (more details in my wiki website). A server with oublic IP at NTNU runs IMCProxy, bridging the IMC stream of messages from the AutoNaut to whatever other node connected to internet (that runs the proxy as well), in this case my laptop. I can therefore receive the UDP payload and stream it in Neptus. However, this in not enough to make me confident running a mission, because I do not have direct access to the BeagleBone over internet. If modifications on the onboard software need to be done or simply rebooting a service (like dune or IMCProxy itself), I need to be able to ssh into the BBB. I am working on it, with the support of Ze Pinto. I hope this will be ready for the next trials.
This to say that for this trials I used p2p WiFi communication with Ubiquiti Rocket radios. I borrowed an antenna dish from the AURLab, and I was able perfectly cover any distance during the mission (up to 4km). I believe that with the directional dish on shore we can go up to around 10-12km LOS. You see the antennas in the pictures, both VHF and WiFi dish.

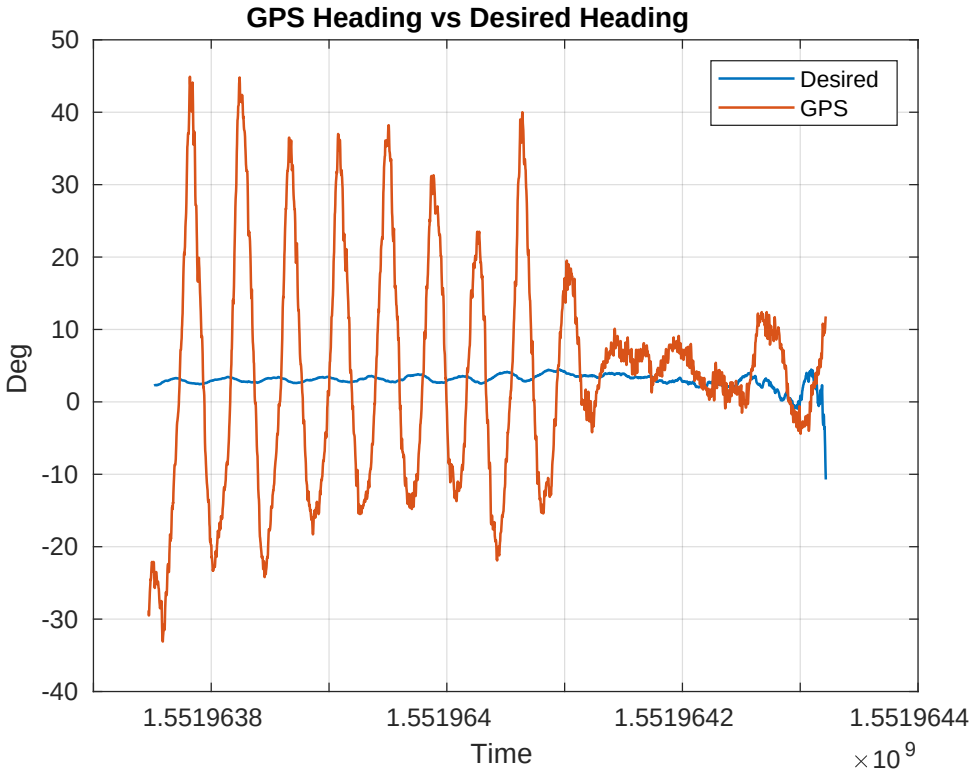
Navigation performances

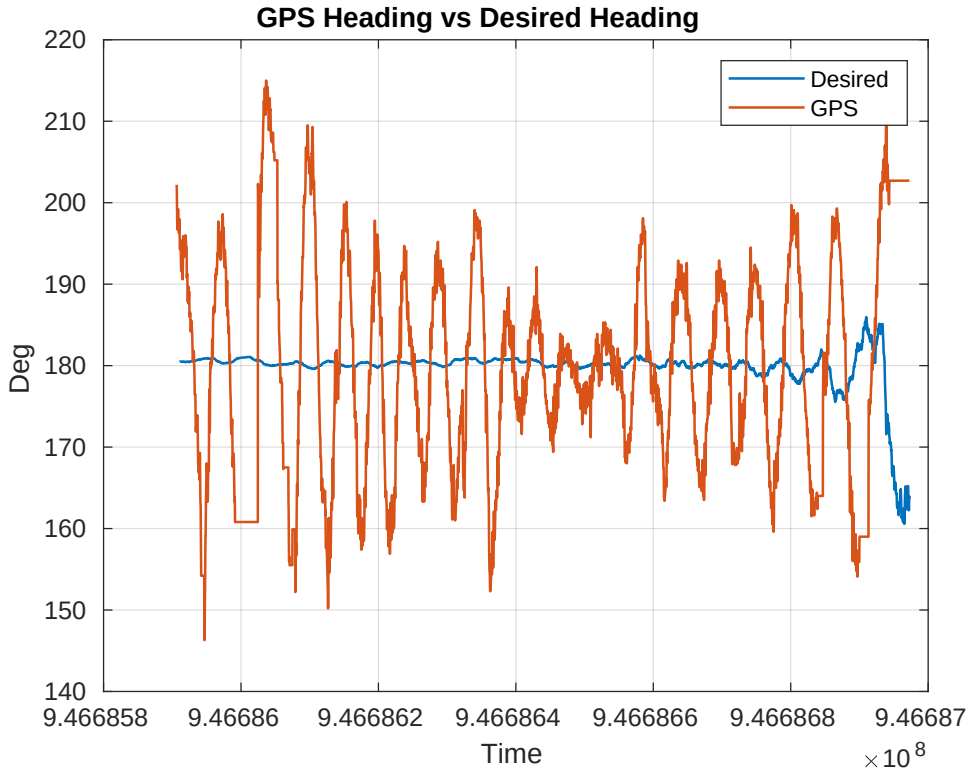
A second purpose of the trials was to test the performances of both autopilots (L1 and L2) and possibly tune the gains. The first limitation that we immediately noticed that GPS COG is not provided by the receivers at very low speeds. Depending on the angle of attack of the waves and on winds, the speed of the AutoNaut may drop considerably, below 0.5kn. This happens especially during sharp turns. The GPS does not provide COG in this case, resulting in a constant error (COG_des - COG_meas). The controller then computes the same rudder angle, that makes the AutoNaut overcome the desired course. Once the COG is again available the controller observes an heading too far from the desired and inverts the rudder direction. This causes considerable oscillations around the desired heading.
Solutions:

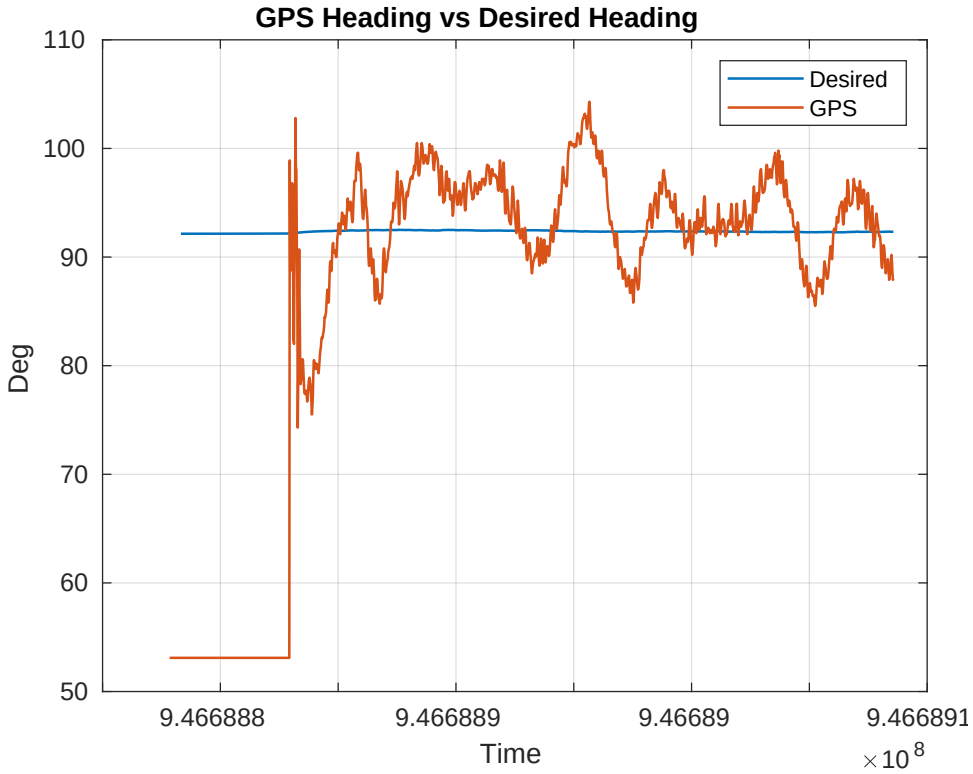
- replace receivers with better quality ones, prividing COG no matter the speed - I have seen a couple of options (one GPS compass, not relying in magnetism, with 2 RS232 outputs - we could give heading and GPS info to both L1 and L2)
- estimate the speed from the position (Kalman Filter) and compute the course given the speed (feasible in Dune, not feasible in the CR6)
- fuse GPS COG and Compass heading (feasible in Dune, not feasible in CR6)

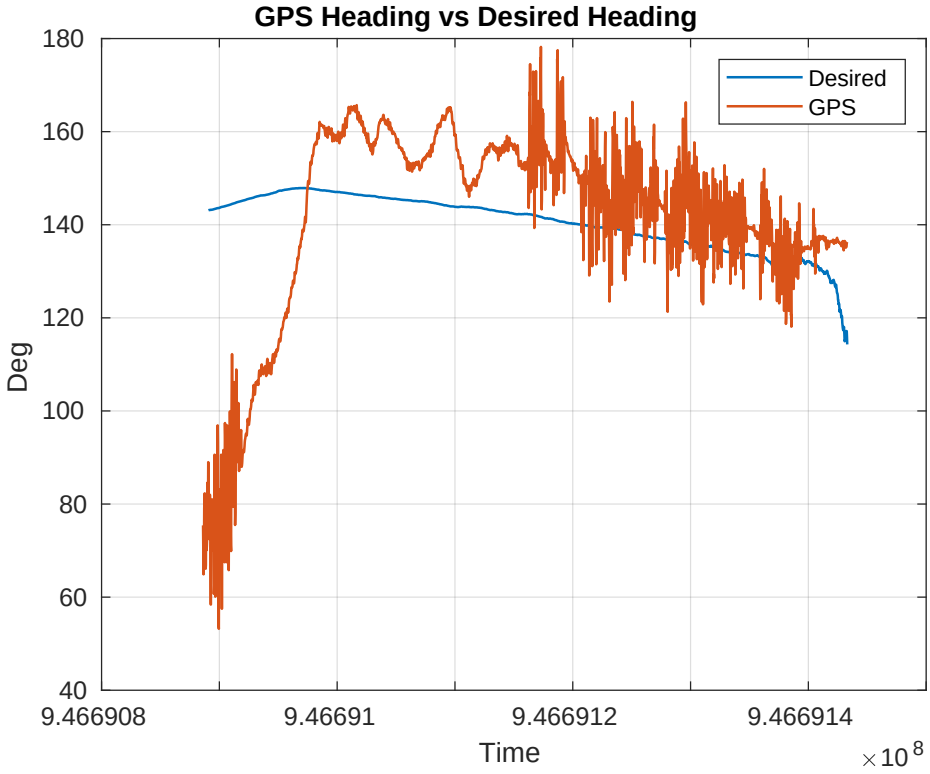
Waypoint Navigation

Here the plots of some of the maneuvers performed during the trials. The maneuvers were simple go_to from one point to another. Plots show desired course and measured one, from the GPS.


GPS Heading vs Desired Heading
Desired
GPS
Deg
Time
50
40
30
20
10
0
-10
-20
-30
-40
1.5519638
1.551964
1.5519642
1.5519644
×10 9


GPS Heading vs Desired Heading
Desired
GPS
Deg
Time
220
210
200
190
180
170
160
150
140
9.466858
9.46686
9.466862
9.466864
9.466866
9.466868
9.46687
×10 8


GPS Heading vs Desired Heading
Desired
GPS
Deg
Time
110
100
90
80
70
60
50
9.466888
9.466889
9.46689
9.466891
×10^8


GPS Heading vs Desired Heading
Desired
GPS
Deg
Time
180
160
140
120
100
80
60
40
9.466908
9.46691
9.466912
9.466914
×10^8

Images

Here some images. The UAV pilot gave me 30GB of videos and pictures of the AutoNaut during the trials. I will upload some in the wiki website. Do not hesitate to ask for them.

Next steps

I am thinking of having sea trials again soon, as soon as I managed to implement remote communication in GLUED, over 4G. The next trials will be devoted to test again the navigation performances, on the basis of the solution adopted to solve the GPS COG issue. Also communication over internet and collision avoidance capabilities will be tested. COLREGS maneuvers are implemented and ready to be tested, as long as navigation capabilities are good enough.