LN2 auto-filling proposal

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Document History

Document Location

This document is only valid on the day it was printed.
Printed on
The document can be found at :
http://www.ing.iac.es/~eng/mechanical/LN2/LN2proposal.pdf

Revision History

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Approvals

This document requires the following approvals.
Signed approval forms are filed in the project files.

Name	Signature	Title	Date of Issue	Version

Distribution

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Introduction or Purpose	

Recently the Liquid Nitrogen auto filling (LN2 auto filling) system has been installed in GRACE.
Different problems have been detected in operating this system in ensuring a correct filling of the three cryostats in GRACE. It became necessary to study the problems and think of possible ways forward aimed to satisfy the initial requirements for this system. For more detail reference is made to file: http://www.ing.iac.es/~eng/mechanical/LN2/LN2investigation.pdf

Note:
In this document a distinction will be made between liquid nitrogen and gaseous nitrogen. Since at ING nitrogen in general is indicated by LN2 we will stick to this terminology. The difference in phase will be mentioned separately. That explains the term liquid LN2 or gaseous LN2, which strictly speaking is not correct.

Scope	

This document will summarize on different options to implement an improved filling system for the cryostats in GRACE. A specialist supplier (Vacuum barrier), that specializes in this kind of equipment has been contacted and they have made us a proposal with different options. In this document the different options will be described and explored how they meet the requirements

Exceptions	

Description of problem	

The adaptive optics suite is housed in GRACE. This special room should provide a stable environment for correct functioning of the AO system. Environmental stability in respect to humidity, temperature, airflow is critical for adaptive optics systems. Especially the Deformable Mirror (DM) is very sensitive to any fluctuations in the above parameters. During the existing LN2 filling procedure of the three cryostats in Grace this environment is disturbed. A dewar has to brought into GRACE to fill the cryostats. Due to the pressurized filling it is necessary to open the double doors to ensure sufficient Oxygen levels inside GRACE. This affects the environmental stability and can result in the need to repeat the calibration and setup of the Adaptive Optics system and the DM in particular, which can be very time consuming.

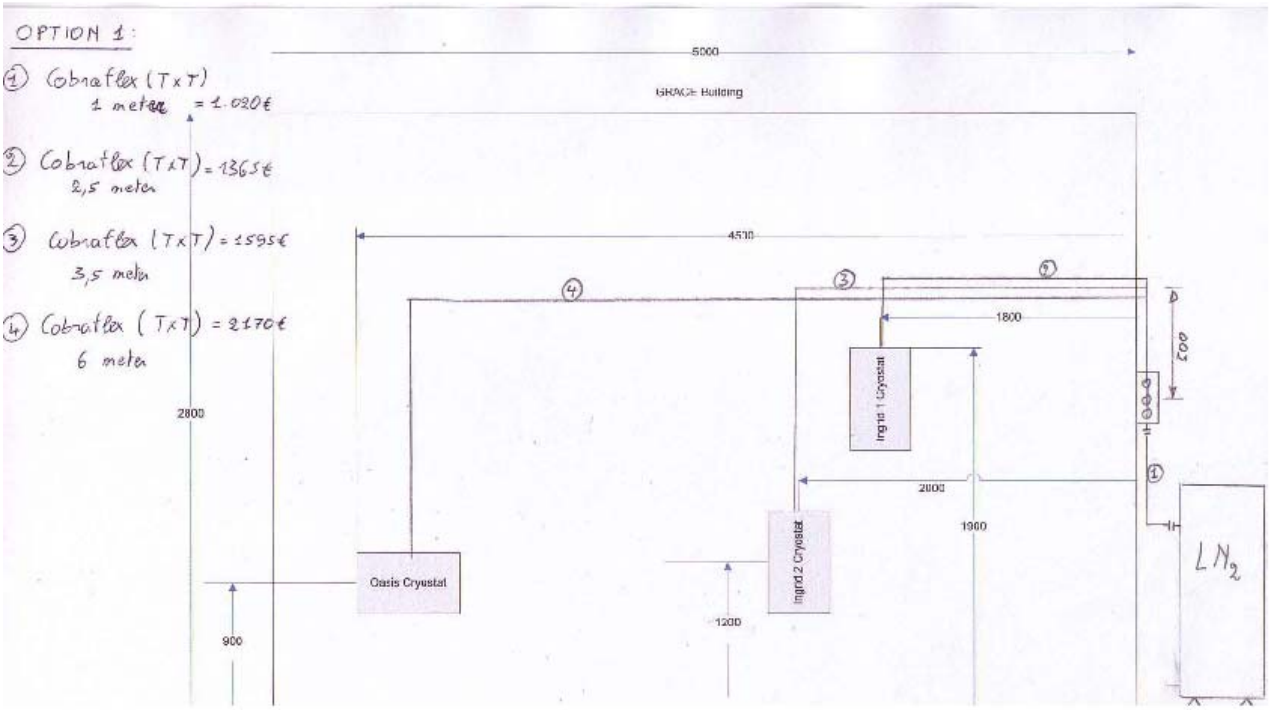
Investigations were started to determine whether an auto-filling system could be implemented.

Requirements	

1. Reduced time for double doors to be opened for ventilation
2. No LN2 spillage on optical bench
3. Dewar placed outside GRACE to avoid knocking of optical bench by bringing dewar in.
4. Limit risk for Oxygen depletion
5. Limit fill times for all cryostats to 10 minutes
6. Safe working system

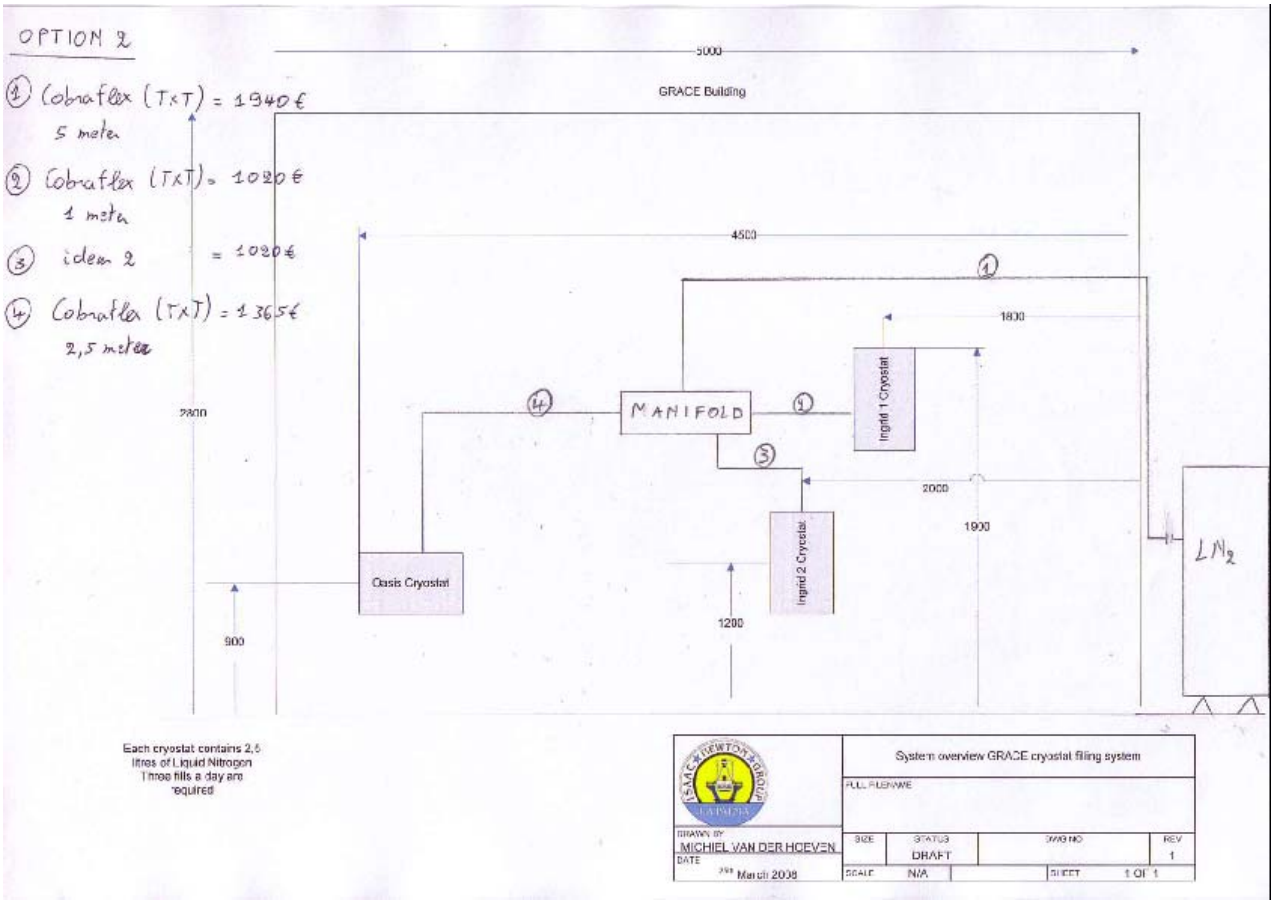
Vacuum Barriers Systems was contacted since they specialize in this kind of equipment.
A system overview was send to them together with the requirements.
They have come back with 4 different options.

Option 1:
Uses existing manifold mounted at the GRACE outside wall.
Existing pipe work will be replaced by vacuum insulated flexible pipes (Cobraflex). Three individual lines from the manifold will be mounted to each cryostat.



No additional valves are required. Total cost: 6.150 Euros

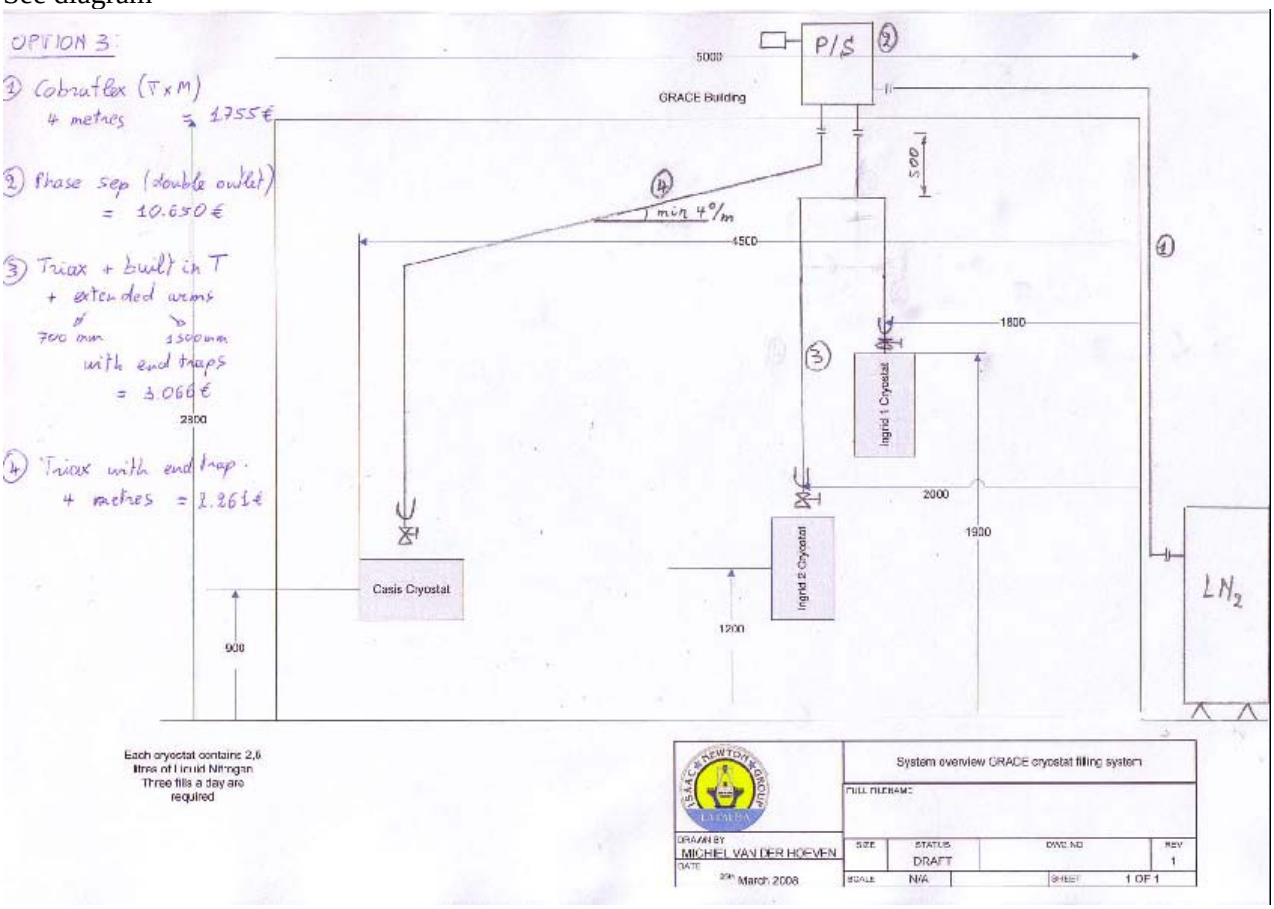
Option 2:
Uses the existing manifold but mounted inside GRACE. The results in a limited amount of vacuum insulated pipe work, since one long common line can be mounted to the manifold that is placed close to the cryostats.



In order to control the flow to each cryostat either manual or electro-magnetic valves are needed.
Cost of the system without these valves using the current valves is: 5.345 Euros
With a

Manual vacuum valve ½" with safety relief valve: 3 x 305 = 915 Euros
Electro-magnetic valve ½" with safety relief valve: 3 x 655 = 1965 Euros

Option 3:
This option uses a different technique for filling by making use of a phase separator. This device will separate liquid from gaseous nitrogen. Liquid nitrogen will be available instantaneously at atmospheric pressure. The phase separator will have to be fitted above the cryostats, probably on the GRACE roof. Special triple vacuum insulated lines (Triax) will be used to connect the three cryostats to the phase separator. A valve (manual or electromagnetic) will control the flow to each cryostat. To stop these valves from freezing when there is no flow an end trap is fitted in each line.
See diagram

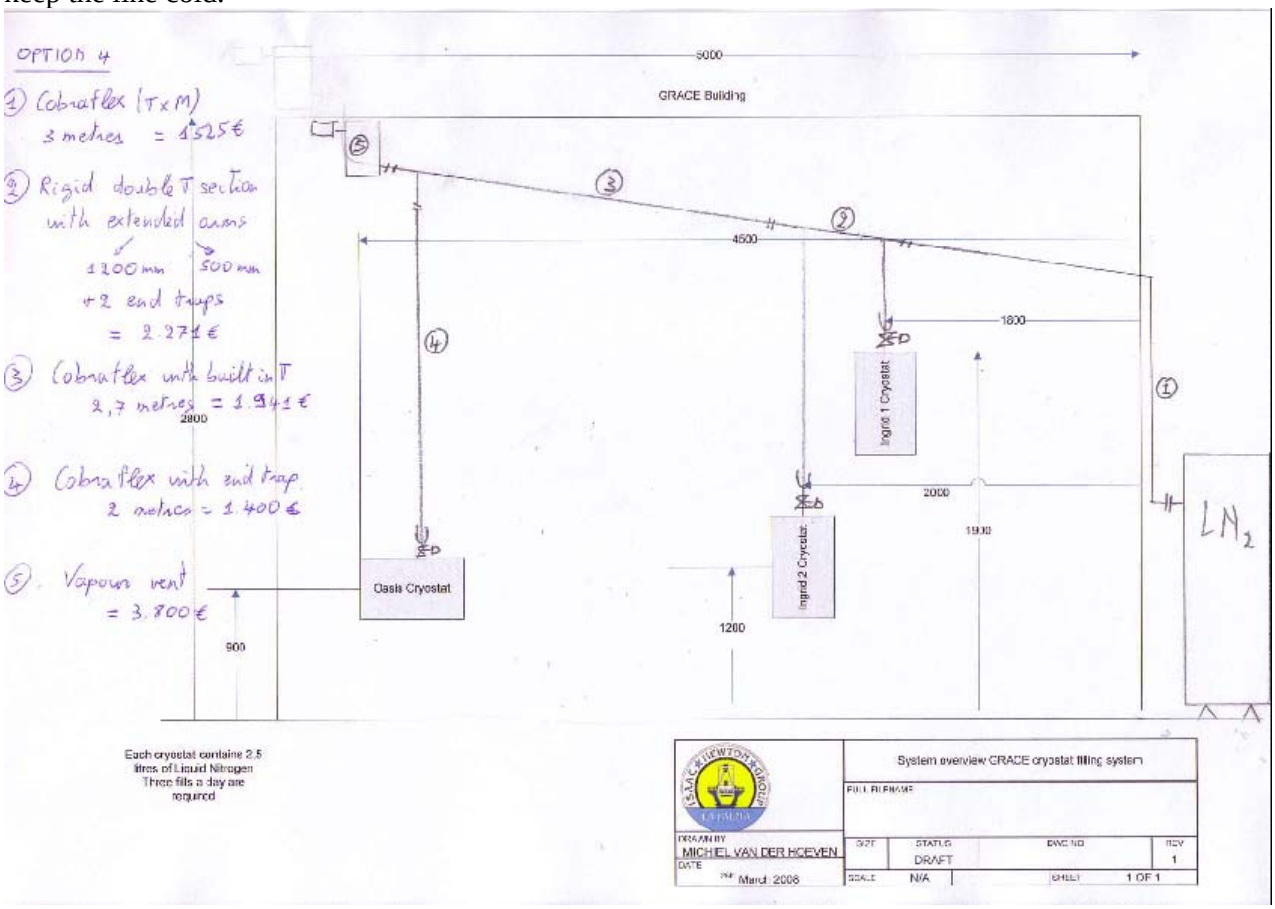


Cost of this system: 17.732 Euros without valves

Manual vacuum valve ½" with safety relief valve: 3 x 305 = 915 Euros
Electro-magnetic valve ½" with safety relief valve: 3 x 655 = 1965 Euros

Total manual control: 18.647 Euros
Automated control: 19.697 Euros

Option 4:
One common Cobraflex line with 3 connections to each cryostat will be mounted. Three (manual/electro-magnetic) valves with end trap will be fitted. In order to keep the line cold at all times a vapour vent will be mounted at the end of the common line at the highest point (out side of GRACE). This way all the gas formed in the line will escape through the vapour vent and keep the line cold.



Total cost: 10.937 Euros

Manual vacuum valve ½" with safety relief valve: 3 x 305 = 915 Euros
Electro-magnetic valve ½" with safety relief valve: 3 x 655 = 1965 Euros

Total manual control: 11.552Euros
Automated control: 12.247 Euros

Selection criteria:

- Functional requirements (reduce double doors open/ knocking/ LN2 spillage)
- Safety requirement (reduce risk oxygen depletion)
- Cost

Decision matrix

Rating 1-3 *1 low score* *3 high score*	**Option 1** Current system replaced by vacuum cobraflex lines	**Option 2** Place manifold in GRACE with cobraflex lines	**Option 3** Phase separator with triax vacuum lines for liquid nitrogen filling	**Option 4** Cobraflex lines with vapour vent to maintain fill line cold permanently
Reduce double door open time	1	1	3	2
Reduce LN2 spillage on optical bench	1	1	1	1
Place dewar outside GRACE	1	1	1	1
Reduce risk oxygen depletion	1	1	3	2
Maximum fill time: 10 min.	1	1	3 (guaranteed by manufacturer)	3 (guaranteed by manufacturer)
Safe working system	1	1	3	2
Total score	6	7	14	11
Cost	6.150	5.345	19.697	12.247

Summary

Option 1,2,4 use conventional way of filling by pressurized nitrogen. This will cause gaseous nitrogen. With option 1 and 2 this gas will be blown off inside GRACE and the double doors need to be opened for ventilation. With option 4 the gaseous nitrogen is blown off outside GRACE, which reduces the disturbance in thermal environment and air flow inside.
Option 3 uses pure liquid nitrogen filling with liquid nitrogen at atmospheric pressure. No gaseous nitrogen is brought into GRACE. The need for opening the double doors might be eliminated as a whole. This is an advantage of this option against the others. Tests should provide information whether the doors can be kept closed with option 4 as well.

Taking cost into account, option 3 probably can not be justified since option 4 satisfies the requirements at a reduced cost.

Tests:
About 5 metres of vacuum insulated flexible hose is available on site. This is similar to what the supplier has specified.
With this equipment tests have been done to determine fill times. 5 Metres of vacuum insulated flexible pipe work delivers liquid nitrogen within 5 minutes after opening the dewar valve. This is with the flexible pipe at room temperature initially. This confirms the rapid response of all these systems.

LN2 losses option 3 and 4:

It is important to have an idea of the added losses in LN2 by the extra components. The vacuum insulated components have minimal losses. The main losses are caused by the valves which are not vacuum insulated.
Please note that the losses of option 3 with the phase separator are very similar to option 4 with the vapour vent.
The main losses are caused by the end traps with the valves, which are common to both systems.

Current LN2 consumption of cryostats in GRACE

Oasis	2	liters
INGRID 1	2	liters
INGRID 2	3	liters

3 fills a day x 7 days/wk = 147 ltr/wk consumption

2 Dewars at GRACE

1	120 litre	x 2 refill/week @ 30% left in dewar	= 168 liters
1	75 litre	x 2 refill/week @ 30% left in dewar	= 105 liters
			---------- +
		Total	273 ltr/wk

Losses: 273 – 147 = 126 ltr/wk
126 litres/week = 0.75 ltr/hr

Added losses of new equipment:

7 metres of Cobra flex vacuum insulated hose:	6.5 Watt/hr = 0.15 ltr/hr
1 Tee-section	2 Watt/hr = 0.05 ltr/hr
1 Vapour vent	5 Watt/hr = 0.1 ltr/hr
3 end traps with electro-magnetic valves,	90 Watt/hr = 1.5 ltr/hr
	Total = 1.8 ltr/hr

In order to further reduce the losses (caused by the end-traps); the valve on the dewar can be left closed until just before a fill needs to take place. Within 10 minutes the line should be filled with liquid nitrogen without blowing any gas into GRACE (the vapor vent sits on the roof). Once the main line is filled; the individual filler pipes can be fitted into the cryostats and filling should be instantaneous from that moment.
With this procedure the added losses would be in the order of 3 ltr/day = 21 ltr/wk which is around 15% increase. If this provides a system that minimizes the disturbance in GRACE this is probably acceptable.

Recommendation:
Option 4 will deliver liquid nitrogen at the filler tubes for each cryostat rapidly. The amount of gas and disturbance in air flow and temperature inside GRACE are minimal. The increased nitrogen consumption is not in the order of magnitude that this should be a major concern, in my opinion.
Total cost:

•	Vapour vent	3.800 Euros
•	Cobraflex 3 metres	1.525 Euros
•	Rigid double T section and end traps	2.271 Euros
•	Cobraflex with build-in T 2.7 metres	1.941 Euros
•	Cobraflex with end trap 2 metres	1.400 Euros
•	3 Electro-magnetic valve ½" with safety relief valve	1.310 Euros
	Total	12.247 Euros

Delivery times on these items need to be confirmed but are to be expected between 6-8 weeks. The July GLAS run starts on the 16th. The system should be installed in the 2nd half of June to be ready for the 1st week of July before the readiness checks. This means that if we want the system to be operational during this run the components should be ordered at the start of May. At the current date it becomes clear that getting this system installed for the July run is not very likely.

References

http://www.asscientific.co.uk/

http://www.vbs.peco-europe.co.uk/mbe.pdf

http://www.vacuumbarrier.com/

Kevin Dee, Engineering & Project Solutions