Position Paper
Exemption of propellant-related use of hydrazine from REACH authorisation requirement

The purpose of this document is to state the common position of the European space industry on the exemption of propellant-related use of hydrazine (EC 206-114-9)[1] for space applications from the authorisation requirement under Regulation (EC) No 1907/2006 (REACH). The substance has been included in ECHA's candidate list on 20 June 2011 and may be prioritized for inclusion in Annex XIV of REACH at any time.

Executive summary

Hydrazine (anhydrous) is a strategic component for satellite and launcher programmes. Due to its high purity quality required for space applications it is not comparable to other industrial uses and grades. Most space vehicles[2] including telecommunication, Earth observation, navigation and scientific satellites as well as space launchers rely on hydrazine and/or hydrazine derivatives propellants. More specifically, all major European programmes such as Ariane 5, Soyuz, Vega, Galileo, GMES and other satellites produced for public Agencies or for private operators use hydrazine. In total, less than 20 tonnes per year of this "space-specified" hydrazine are currently being used within the European Union for the mentioned missions.

Against this background timely preparation for the required formalities to comply with the REACH authorisation process is imperative for conductance of current and future space operations.

Therefore a task force, open to all users of hydrazine in the European space industry, was set up in October 2011 under co-ordination of the European Space Agency (ESA) with the aim of determining the route to follow: Authorisation or exemption. In November 2011 a *data evaluation questionnaire* was circulated by Eurospace to all known EEA-based companies actually or potentially using hydrazine as well as to national space agencies (CNES in France and DLR in Germany), in order to obtain a complete understanding of the different handling steps and conditions of use, and allow an assessment of the applicability of REACH authorisation exemption clauses.[3] In parallel, an exemption feasibility study with similar scope was performed by one of the task force members, Astrium Satellites (UK), supported by all major European satellite integrators.[4] Further, companies mapped their activities in the EEA supply chain for hydrazine step by step in process flows.

During the assessment, the UK REACH and CLP helpdesk at HSE[5] and the German REACH-CLP Helpdesk at the Federal Institute for Occupational Safety and Health (BAuA),[6] commented on the case, and advised contacting European Commission and ECHA in order to obtain an authoritative clarification.

Based on the assessments carried out, the European space industry is of the opinion that all propellant-related use of hydrazine for space applications is exempted from REACH authorisation subject to the criteria given in this paper.

[1] Including CAS Number 302-01-2 for the anhydrous form and CAS Number 7803-57-8 for the hydrated form.
[2] For the purpose of this Position Paper the term *space vehicle* refers to satellite systems, probes and space launch vehicles. Space vehicles are procured by governments, public institutions (military and civil) and commercial entities in Europe and worldwide.
[3] The drafting of the questionnaire and assessment of exemption clauses based on the information received were carried out by the consultant REACHLaw Ltd (Finland), who was contracted by ESA for this purpose.
[4] Assisted by the consultancy ERA Technology Ltd (UK) and supported by the companies OHB, TAS and SSTL.
[5] Helpdesk references: 1412DXG11-2375 and 1412DLS11-0003.
[6] Helpdesk reference GZ: 5.0-720 34/04/2011.2172.

1. *Overview of propellant-related use of hydrazine in the European space industry*[7]

Hydrazine anhydrous is a liquid, which is eventually used as an energetic material (propellant) in thrusters of launchers (upper stages) for satellites and satellites themselves (after separation from the launcher). The *function* of hydrazine-based propellant for space vehicles is to generate thrust for orbit change, attitude control and orbit manoeuvring.

The substance hydrazine is primarily used as monopropellant, but may also be used in bipropellant systems. *Monopropellant* use means that hydrazine is decomposed using a catalyst under high temperatures in the propulsion system of the space vehicle, where hydrazine is decomposed completely into a hot gas (ammonia, nitrogen and hydrogen), which is emitted to the outside as exhaust through a nozzle. In *bipropellant* systems hydrazine is combusted completely within a combustion chamber using an oxidizer to induce a hypergolic reaction, the combustion gases are ejected through a nozzle.

Prior to the target application as propellant, a number of handling steps and tests (together also referred to as *mandatory precursor uses*) are necessary:

Presently, the EEA supply chain for hydrazine anhydrous starts with its importation from outside EEA (China, Russia, Japan, USA, etc.). Upon importation, samples of hydrazine are *chemically analysed* at different stages to determine conformance to the specifications for the propellant use.[8] If required, a *purification* process is applied in order to achieve compliance with the specification. *Transfer from one container to another* of hydrazine may be needed for delivery of the right quantity to the customer or the launch site; this also includes *pressurization with inert gases (N_2, He)* of the drums for storage and transport. For the purpose of the final propellant application hydrazine drums are shipped to Centre Spatial Guyanais (CSG), the European spaceport and launch facility near Kourou in French Guiana, where the EEA supply chain ends. At CSG, the substance is *loaded into the tanks of the space vehicle* to be *consumed during its flight*.

Furthermore, during the research and development as well as the qualification and acceptance phase of new space propulsion components hydrazine anhydrous is used on ground in EEA for the mandatory *hot firing test of thrusters* as well as *material compatibility checks*. Hydrazine use for these purposes or *chemical analysis* (see above) – altogether also referred to as *test uses* – normally leads to the consumption of the respective volumes.[9]

All handling steps and test uses are accompanied by specific procedures for *decontamination, cleaning of equipment and waste disposal*. Today, approx. 50-60 workers in total are involved in the handling of hydrazine anhydrous within the EU; they are specially trained and protected through adequate measures preventing exposure to the substance.

In the near future companies in the European space industry are also planning to secure the sourcing of hydrazine from within the EEA, thereby avoiding today's weakness due to importation from outside EEA which can be considered as a major concern for Europe's access to space. Sourcing anhydrous hydrazine within EEA can be achieved by *purification from hydrazine hydrate* manufactured within EEA.

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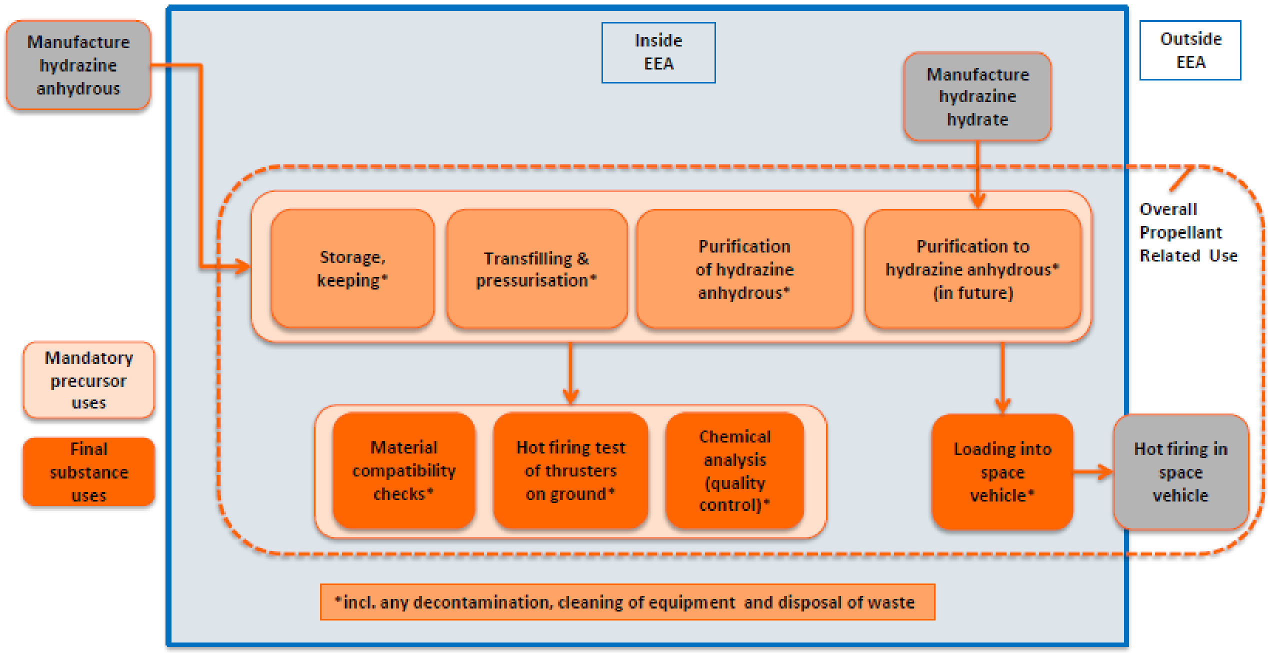
[7] The information in this section and Annex 1 of this Position Paper has been obtained by consolidation of the data received from the entities that answered to the questionnaire circulated by Eurospace (the association of European space industry).
[8] US standard MIL-PRF-26536E.
[9] During the test use or by destruction of residues from it.

The following diagram provides a graphical overview of all mandatory handling steps and tests with hydrazine in the EEA leading up to its final application as propellant in space vehicles.

Propellant-related use of hydrazine in the European space industry



In terms of protection of human health and the environment, the guiding principle for all propellant-related use of hydrazine in the European space industry has always been prevention of worker exposure and environmental releases. To this end companies have been continuously implementing

- state-of-the-art technical hardware to enclose the substance during use;
- well-defined processes for all critical steps, that could harm health or environment;
- special facilities being equipped with monitoring and protection devices;
- training of highly skilled workers;
- other risk management standards, such as use of sophisticated personal protective equipment, for any case of accidental release;
- laws and regulations, which aim to protect worker safety and the environment.

The different steps of hydrazine propellant-related use in the European space industry outlined above as well as associated means of containment, exposure control and other risk management standards are explained in more detail in Annex 1 of this Position Paper, and are further illustrated in process flows relating to eventual use in satellites, launchers and ground test activities for thruster hot firing.[10]

[10] See list of *related documents* at the end of this Position Paper.

2. *Legal grounds for the exemption*

In the opinion of the European space industry all propellant-related use of hydrazine on ground in EEA is exempted from REACH authorisation according to REACH Article 56(4)(d) *"use as fuels in closed systems"*, subject to the criteria given hereafter. In addition, other REACH provisions limiting the scope of authorisation are in our view applicable to certain phases of the propellant-related use of hydrazine, namely REACH Article 3(3) for hot firing in space vehicles, REACH Articles 56(3)1 and 3(23) for test applications and REACH Article 2(2) for the decontamination, cleaning of equipment and waste disposal steps.

2.1. *Hot firing in space vehicle as exempted article use*

Hot firing of hydrazine within the space vehicle being the target application[11] is in REACH terms seen as use of an article (REACH Article 3(3)) with a substance as its integral part. This conclusion has been reached by applying Section 2.4. of the ECHA *guidance on requirements for substances in articles*,[12] including the indicative questions under step 4 and 5, and comparison with relevant cases given in Appendix 1 of the guidance.[13] As a consequence, the hot firing of hydrazine within the space vehicle is not subject to authorisation and the uses of hydrazine as a substance end with its loading into the propellant tank.

Furthermore, hot firing in space vehicles is occurring outside EEA REACH territory in space,[14] except for the Vega launcher in case the firing starts at lower altitude (<100 km) for roll control and re-entry vehicles (e.g. IXV) for guidance and navigation control.

2.2. *Propellant-related use of hydrazine on ground as a case covered by REACH Article 56(4)(d)*

From the wording of REACH Article 56(4)(d) 2nd alternative two conditions can be derived:

- Use of substances as fuels
- Use in closed systems.

The fulfilment of these conditions for all propellant-related use of hydrazine on ground follows from the interpretations given hereafter:

2.2.1. *Use of substances as fuels*

This first condition defines the principal scope of REACH Article 56(4)(d) 2nd alternative.

All identified handling steps and test uses of hydrazine on the ground in EEA are *substance uses* in terms of REACH Article 3(24).[15]

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[11] See detailed description in Annex 1, Section 1 to this Position Paper.
[12] Version 2, April 2011.
[13] See Annex 2 to this Position Paper detailing the article determination according to Section 2.4. of the guidance and comparison with relevant cases from Appendix 1 of the guidance.
[14] Within the scope of the *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies*, in: United Nations Treaties and Principles on Outer Space, UN, New York, 2002.
[15] This also applies to the *hot firing test of thrusters*. Contrary to hot firing in space vehicles, hydrazine is not becoming an integral part of an article in this case, but remains (until consumption) a distinct substance flowing in the closed

Hydrazine anhydrous is also a *"fuel"* in the sense of REACH Article 56(4)(d). The term *"fuel"* is not defined in the REACH Regulation. In our opinion *"fuel"* is to be interpreted as a *material that is used as an energy source*. Further to this, Article 3(24) of Directive 2010/75/EU[16] contains a legal definition of *"fuel"* meaning *"any solid, liquid or gaseous combustible material"*. Hydrazine anhydrous is a liquid combustible material, which is used as an energy source for space vehicle flights by means of hot firing, and hence a *"fuel"* in the sense of both definitions. Further, Directive 2009/43/EC (Annex, ML8.c.4.a.)[17] acknowledges hydrazine anhydrous[18] as *"fuel"* explicitly. Any distinction between monopropellant vs. bipropellant systems would therefore be unjustified. Both processes are essentially hot firing under high temperatures in order to generate thrust. REACH Article 56(4)(d) 2nd alternative does not require that the mode of releasing the energy actually has to be combustion. Indeed, this may be required for REACH Article 56(4)(d) 1st alternative *"use as fuel in mobile or fixed combustion plants of mineral oil products"*, but combustion is not mentioned in the second alternative.

In order to be meaningful, the scope of REACH Article 56(4)(d) 2nd alternative should cover the *overall use* of the substance,[19] including the final substance application and all mandatory precursor uses after its manufacture or import which are associated with the target application for which the substance is actually placed on the market by the manufacturer or importer.[20] Presently, the target application is the hot firing of fuel-grade hydrazine anhydrous within the space vehicle. All identified handling steps and test uses after the substance import[21] up to the loading of the fuel into the propellant tank of the space vehicle as final substance application in REACH terms are associated with this propellant use and should therefore be covered by Article 56(4)(d). They would share common considerations if an authorisation was required, especially regarding analysis of alternatives (use of an alternative propellant? time-lines for substitution?) and socio-economic analysis (impacts of continued use vs. non-use on competition, employment, operating costs, future non-/availability of certain space based assets for European governments, etc.?). Hence, all these steps belonging to the *overall propellant-related use* should be covered by REACH Article 56(4)(d).

Any other interpretation would be contrary to the comprehensive exemption for fuel uses introduced by the REACH legislator in Article 56(4), which includes fuel uses covered by existing specific Community legislation, namely *use as motor fuels covered by Directive 98/70/EC*[22] (lit. (c)), and further extends to fuel uses not covered by specific Community legislation, namely *uses as fuel in mobile or fixed combustion*

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hydrazine supply system, i.e. from the tank - being an external part of the ground test facility - via the connection pipe into the thruster, see more detailed description of this use in Annex 1, Section 5 to this Position Paper.

[16] Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) (Recast).

[17] Directive 2009/43/EC of the European Parliament and of the Council of 6 May 2009 simplifying terms and conditions of transfers of defence-related products within the Community.

[18] *"Hydrazine (CAS 302-01-2) in concentrations of 70 % or more."*

[19] In this sense also BAuA, answer of 21.2.2012, helpdesk reference GZ: 5.0-720 34/04/2011.2172: *"Es sind nicht die einzelnen Anwendungsschritte sondern die gesamte Verwendung zu betrachten."*

[20] The same would apply to other authorisation exemption clauses, as they are typically referring to final substance applications, e.g. uses as intermediates (REACH Article 2(8)(b)), in plant protection products (REACH Article 56(4)(a)) or in biocidal products (REACH Article 56(4)(b)).

[21] And in the future after *manufacture* of hydrazine hydrate within EEA and supply to the EEA-based company that will then perform purification to fuel-grade hydrazine anhydrous for propellant use within the scope of REACH Article 56(4)(d) as a downstream user.

[22] Directive 98/70/EC of the European Parliament and of the Council of 13 October 1998 relating to the quality of petrol and diesel fuels.

plants of mineral oil products and *use as fuels in closed systems* (lit. (d)). Importantly, not accepting the application of REACH Article 56(4)(d) to fuels used in space vehicles due to the article classification derived in accordance with the ECHA guidance[23] would also imply non-applicability of REACH Article 56(4)(c) to motor fuels in vehicles, thereby depriving both provisions of their meaningful scope.

2.2.2. Use in closed systems

The REACH Regulation does not explicitly define *"closed systems"*. In our opinion the term can be interpreted as follows:

> *"Closed system"* in the sense of REACH Article 56(4)(d) is a combination of state-of-the-art technical installations and procedures, that are designed to prevent exposure of humans to the substance or releases to the environment during its use to the maximum possible extent, resulting in a high integrity contained system where no or only little potential exists for exposures[24]. Adequate risk management standards are in place for any case of unintended release. A closed system can be established by applying the criteria for strictly controlled conditions (SCC) in REACH Article 18(4), in association with the ECHA guidance on intermediates, to the relevant use.

Indeed, hydrazine propellant use is not an intermediate use according to REACH Article 3(15). Nevertheless, the definition in REACH Article 18(4) can in our opinion well be seen as a description of the conditions of a *"closed system"* in the context of REACH Article 56(4)(d), which can be practically established in connection with the ECHA guidance on intermediates.[25] Already the legal text implies that the system described in REACH Article 18(4) is equally understood as a closed system.[26] It should also be noted that in the frame of registration Article 18(4) applies fully to substances meeting the criteria of REACH Article 57, i.e. to substances which are (potentially) subject to authorisation.

European space industry considers their systems for hydrazine propellant-related use as closed systems according to the aforementioned definition. This can be confirmed through dedicated in-house audits.

[23] See above Section 2.1. and Annex 2 to this Position Paper.
[24] See also ECHA guidance on information requirements and chemical safety assessment, Chapter R.12: Use descriptor system, Version 2, March 2010, Appendix R. 12-3: Descriptor-list for process categories (PROC), PROC 1, Examples and explanations, p. 22.
[25] In this sense also BAuA, answer of 21.2.2012, helpdesk reference GZ: 5.0-720 34/04/2011.2172: *"Wenn Ihre Anwendung grundsätzlich durch Art. 56 Abs.4 d) abgedeckt wäre, könnte der Leitfaden herangezogen werden, um die Geschlossenheit zu belegen."*
[26] See REACH Article 18(4)(d): *"in the case of cleaning and maintenance works, special procedures such as purging and washing are applied before the system is opened and entered;"*.

2.3. Test uses as a case covered by REACH Articles 56(3)1 and 3(23)

From the wording of REACH Articles 56(3)1 and 3(23) setting out an exemption for substance uses in scientific research and development (abbreviation *"SRD"*) two conditions can be derived:

- Use of substances in any scientific experimentation, analysis or chemical research
- Carried out under controlled conditions in a volume less than one tonne per year per legal entity.

If not already covered by REACH Article 56(4)(d), the fulfilment of these conditions for all test uses of hydrazine on the ground – including *hot firing test of thrusters, material compatibility checks* and *chemical analysis*[27] – follows from the interpretations given hereafter:

2.3.1. Use of substances in any scientific experimentation, analysis or chemical research

All test uses with hydrazine on ground in EEA are *substance uses* in terms of REACH Article 3(24).[28]

ECHA has recognized that the SRD exemption can cover activities for monitoring/quality control purposes:[29]

- *SRD activities can cover analysis for monitoring or quality control purposes;*
- *Therefore, in principle a substance may be exempt from authorisation if used, on its own or in a mixture, in analysis for monitoring and quality control purposes, for instance, in order to monitor the presence or concentration of that substance or other substances;*
- *Only substances used directly for research or analytical purpose, whether on their own, in mixture or in conjunction with analytical equipments, can benefit from the SRD exemption. This excludes from the exemption any substances forming an integral part of an analytical device.*

All test uses in question are activities for monitoring or quality control purposes:

- During *chemical analysis*, samples of hydrazine anhydrous are analysed in order to monitor its purity and to determine conformance with a standard (e.g. MIL-PRF-26536E), i.e. whether it has the required quality for use in space vehicles.
- *Material compatibility checks* are carried out during the development and qualification phase of new space propulsion components (e.g. ECSS-E-ST-35-10C). The purpose of the testing is to determine compatibility of materials used in hydrazine propulsion systems (e.g. elastomeric and metal materials, sealing). To this end the materials are stored in very small quantities of hydrazine liquid (e.g. <500 ml). Hence, hydrazine is directly used in analysis for monitoring and quality control purposes, in order to monitor the impact of hydrazine on these materials. It is not necessary and not required by the wording of REACH Article 3(23), that the substance is itself the object of the analysis (see also ECHA comment above *"or other substances"*).
- *Hot firing test of thrusters* means hot firing of hydrazine for testing purposes when developing new thrusters as well as during the qualification and acceptance phase to approve new designs of thrusters.[30] As already highlighted, the hydrazine cannot be seen as an integral part of the test

[27] See detailed descriptions of these uses in Annex 1, Sections 3. – 5. to this Position Paper.
[28] See already above Section 2.2.1.
[29] See for example Responses to Comments Document (RCOM) on ECHA's Draft 3rd Recommendation for Trichloroethylene (EC number: 201-167-4) of 20 December 2011, pages 3 and 4.
[30] See overview of different purposes of hot firing testing in Annex 1, Section 5. to this Position Paper.

specimen or ground test facility equipment, but is used as a distinct substance which is flowing in the hydrazine supply system and hence is used in conjunction with the technical hardware necessary for the testing.

To the extent handling steps are necessary prior to the actual SRD activity (e.g. transfilling into smaller containers, storage or purification), they are in our opinion equally covered by the scope of the SRD exemption, because they are mandatory precursor uses for the SRD use.[31]

2.3.2. Carried out under controlled conditions in a volume less than one tonne per year

The REACH Regulation does not explicitly define *"controlled conditions"*. In our opinion the term can be interpreted as follows, taking into account ECHA's responses to comments on its draft 3rd recommendations for substances to be included in Annex XIV:[32]

> *"Controlled conditions"* in the sense of REACH Article 3(23) are a combination of technical installations, procedures and risk management standards that provide a coherent system to limit exposure of humans to the substance or releases to the environment during the scientific experimentation, analysis or chemical research, which takes into account the intrinsic properties of the substance, notably those leading to the inclusion in Annex XIV. Such *"controlled conditions"* may be established by applying the tighter criteria for *"strictly controlled conditions"* in REACH Article 18(4), in association with the ECHA guidance on intermediates, to the relevant use.

European space industry considers their conditions for test uses of hydrazine as controlled according to the aforementioned definition. This can be confirmed through dedicated in-house audits.

2.4. Decontamination, cleaning of equipment and waste disposal steps as a case of REACH Article 2(2)

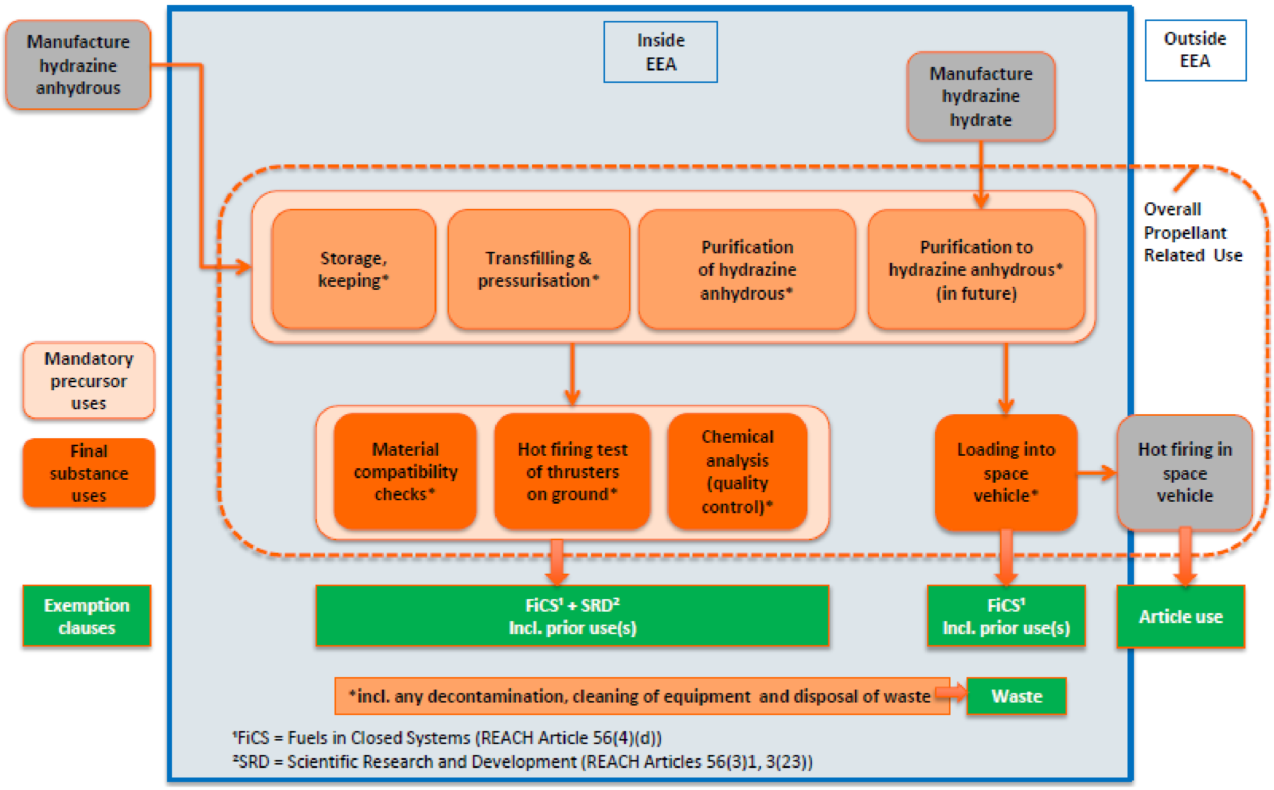
If not already covered as an integral part of the overall use exempted according to REACH Article 56(4)(d) and/or REACH Articles 56(3)1 and 3(23), *decontamination, cleaning of equipment and waste disposal* involving hydrazine are in our opinion regarded as waste treatment, which is done in accordance with the waste legislation, and hence not downstream uses under REACH.[33] According to Directive 2008/98/EC on waste, which has replaced Directive 2006/12/EC, *'waste' means any substance or object which the holder discards, or intends or is required to discard;"* (Article 3(1)). In our opinion accidental and unexpected spillage or release and disposal of un-used leftovers of hydrazine which are subject to specific cleaning or decontamination procedures, are by definition already waste from the moment of spillage, release or being left over, as the user *"intends or is required to discard"* them.

[31] See corresponding reasoning other than relating to the specific aspects of the use as fuel in Section 2.2.1.
[32] See for example Responses to Comments Document (RCOM) on ECHA's Draft 3rd Recommendation for Trichloroethylene (EC number: 201-167-4) of 20 December 2011, page 4, footnote 1.
[33] See ECHA, Guidance on registration, Version 1.6, January 2011, Section 1.6.3.4, p. 33.

3. *Conclusions*

The exemption position of the European space industry is summarized in the following diagram.

Exemption of propellant-related use in the European space industry from REACH authorisation



This document has been written by the *Hydrazine REACH Authorisation Task Force of the European Space Industry*, reflecting the best knowledge available from experts in their field, thanks in particular to the support of the following corporations:

AMPAC-ISP Europe
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SURREY SATELLITE TECHNOLOGY LTD (SSTL)
THALES ALENIA SPACE (TAS)

and space agencies:

European Space Agency (ESA)
Centre National d'Etudes Spatiales (CNES)
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This Position Paper and the assessments on which it is based have been made following collection of relevant use-related information from industry through careful analysis of the REACH legal text and other relevant EU legislation, taking into account the existing ECHA guidance and ECHA's responses to comments documents on its previous draft Annex XIV recommendations. The Position Paper may be updated in light of new interpretations by the European Commission or new ECHA guidance.

Annexes to the Position Paper

- Annex 1: *Descriptions of propellant-related use of hydrazine in the European space industry*
- Annex 2: *Article determination of hot firing in space vehicles according to ECHA guidance on substances in articles*

Related documents to the Position Paper

The following documents relating to this Position Paper are collected in a separate zip file:

- *1 - European Space Agency (ESA) letter of support (ref. D-TEC/2012.70), May 25th, 2012.*
- *2 - CNES letter of support (N/Réf.: IGQ//QC 2012. 08319, May 30th, 2012*
- *3 - Answer dated of German REACH-CLP Helpdesk at the Federal Institute for Occupational Safety and Health (BAuA), helpdesk reference GZ: 5.0-720 34/04/2011.2172, February 21st, 2012.*
- *4 - Answer of the UK REACH and CLP helpdesk at HSE, helpdesk references: 1412DXG11-2375 and 1412DLS11-0003, December 14th, 2011.*
- *5 - Hydrazine Process Flow - European Satellite Suppliers (EEC Launch Facility), April 27th, 2012.*
- *6 - Hydrazine Process Flow - European Launch provider (EEC Launch Facility), April 26th, 2012.*
- *7 - Hydrazine Process Flow – Ground Test Activities for Thruster Hot Firing, April 27th, 2012.*

Annex 1 to Position Paper

Descriptions of propellant-related use of hydrazine in the European space industry

This Annex details the different steps of hydrazine propellant-related use subject to the present Position Paper as well as associated means of containment, exposure control and other risk management standards.[34] The information is a consolidation of data that have been collected from actual and potential users of hydrazine in the European space industry in the frame of the Hydrazine REACH Task Force co-ordinated by the European Space Agency (ESA) from November 2011 until February 2012.[35]

1. *Hot firing in space vehicles (target use)*

Hydrazine anhydrous is a liquid, which is eventually used as an energetic material (propellant) in thrusters of launchers (upper stages) for satellites and satellites themselves (after separation from the launcher). The *function* of hydrazine-based propellant for space vehicles is to generate thrust for orbit change, attitude control and orbit manoeuvring.

The substance is primarily used as monopropellant, but may also be used in bipropellant systems. *Monopropellant* use means that hydrazine is decomposed using a catalyst under high temperatures in the propulsion system of the space vehicle, where hydrazine is decomposed completely into a hot gas (ammonia, nitrogen and hydrogen),[36] which is emitted to the outside as exhaust through a nozzle.[37] In *bipropellant* systems hydrazine as a fuel component is combusted completely within a combustion chamber using an oxidizer to induce a hypergolic reaction, the combustion gases are ejected through a nozzle.

Compatibility of hydrazine with materials used in the units (valves, tanks, thrusters) of the propulsion systems is critical for achieving its function throughout the space mission. Hydrazine propulsion technology is based on more than 50 years of space experience resulting in a very well understood technology with a very high degree of heritage and reliability.

The propulsion use of hydrazine in space vehicles is generally for the very high altitude flight only, i.e. it takes place outside the atmosphere and far away from the soil, normally outside EEA REACH territory in space,[38] except for the Vega launcher in case the firing starts at lower altitude (<100 km) for roll control and re-entry vehicles (e.g. IXV) for guidance and navigation control.[39]

The entire system is controlled thoroughly (tightness, functional and measurement tests) prior to fuelling of the tanks. Propulsion systems are designed to comply with the launch site safety requirements and international recognised norms such as MIL-STD-1522A and ECSS-E-ST-32-02C. Multiple independent

[34] See further the illustration of these steps in separate process flows relating to eventual use in *satellites*, *launchers* and *ground test activities for thruster hot firing* in the documentation enclosed with this Position Paper.
[35] The data evaluation questionnaire and consolidation of data received were carried out by the consultant REACHLaw Ltd. (Finland), who was contracted by ESA for this purpose.
[36] With no hydrazine present.
[37] See ECHA, Annex XV dossier for Hydrazine, February 2011, p. 51, for more details about the monopropellant use.
[38] Within the scope of the *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies*, in: United Nations Treaties and Principles on Outer Space, UN, New York, 2002.
[39] The propulsion in Vega launchers may start at approx. 2 500 m altitude and during re-entry IXV may use propulsion up to an altitude of 20 km.

barriers (diaphragm of the tank, various valves, electrical barriers) are built and tested in the propulsion system against inadvertent hydrazine losses.

All launching operations take place at a dedicated launch complex with restricted access under stringent safety conditions (Centre Spatial Guyanais, French Guiana).

2. Filling into the tank of the space vehicle ("loading")

The filling with hydrazine for the target use in space vehicles is carried out at a dedicated filling station from a pressure drum directly to the propellant tank(s) by gas pressurising, through a tube or flexible directly connected to the drum. The gas pressure pushes out the liquid from the drum to the tank. The hydrazine fuelling equipment is designed as a closed system consisting of the following stages: Pressure drum – piping/flexible – control valves – propellant tank.

The loading of hydrazine always takes place at Centre Spatial Guyanais (CSG), the European spaceport and launch facility near Kourou in French Guiana.

All fuelling process steps are designed to protect worker safety and environment, and are described in detail in the relevant procedures (available with the corresponding fuelling service provider). These include for example:

- The loading of hydrazine always takes place in a dedicated room equipped with specific monitoring tools and rules for such propellant operations.
- The ground hardware used to fill the space vehicle is designed to comply with the launch site / testing facility safety requirements and national laws.
- All ground filling equipment is proof and leak tested before each activity, as is the space vehicle.
- All liquid and gas lines are monitored during valve opening and liquid flow to verify that the closed system is leak-tight.

Workers are highly skilled and regularly trained. Workplace and workers are monitored by gas detectors. Workers always wear special personal safety equipment like hermetic scape suits or breathing helmets, both with independent breathing air supply, and protective clothes as precaution when fuelling the space vehicle. Emergency processes and facilities are on standby if required.

The filling facility is connected with a waste air treatment facility / gas washer equipment, which serve to remove any residual vapour of hydrazine and notably include dedicated neutralization systems.[40]

In exceptional cases, the loading process is reversed (*unloading*), e.g. for qualification purposes, using the same ground hardware, processes and workers.

3. Chemical analysis

Quality control of the hydrazine needs to be carried out, before it can be used within the space vehicle. Anhydrous hydrazine that is used by the EU space sector needs to comply with the US standard MIL-PRF-26536E. This standard describes the purity grades of anhydrous hydrazine, i.e. the acceptable composition of hydrazine propellant for space applications. The purpose of the analysis is to confirm conformance to the standard. To this end, a low amount of hydrazine (in any case far below 1 tonne per year per downstream user) will be used for chemical analysis.

[40] Potential remaining of hydrazine will normally be classified as waste and no further usage applies, see 11. of this Annex.

All analysis is covered by analytical procedures (chromatograph, spectrograph, etc.) that are solely undertaken in a closed environment (glove box/fume cupboard) thereby precluding worker exposure.

Workers are trained chemists. Workplace and workers are monitored by gas detectors. Workers always wear special personal safety equipment. At the end of the testing hydrazine is destroyed.[41]

4. Material compatibility checks

Material compatibility checks using hydrazine are carried out during the development and qualification phase of new space propulsion components (e.g. ECSS-E-ST-35-10C). The purpose of the testing is to determine compatibility of materials used in hydrazine propulsion systems rather than testing of the hydrazine itself (i.e. its suitability as fuel). Hydrazine is tested for compatibility against various materials (e.g. elastomeric and metal materials, sealing). To this end the materials are normally stored in very small quantities of hydrazine liquid (e.g. <500 ml), in any case far below 1 tonne per year per downstream user.

All analysis is covered by analytical procedures that are solely undertaken in a closed environment (glove box/fume cupboard) precluding any atmospheric exposure. The storage of materials in hydrazine takes place under controlled conditions (temperature, pressure).

Workplace and workers are monitored by gas detectors. Workers always wear special personal safety equipment. At the end of the testing hydrazine is generally destroyed.[42]

5. Hot firing test of thrusters on ground

During the research and development as well as the qualification and acceptance phase for thrusters hydrazine is used for hot firing on ground in a dedicated test facility. Test facilities are currently located in Germany and UK. Hydrazine usage for test of thrusters is currently below 1 tonne per year per downstream user performing these tests.

The hot firing test, which may relate to monopropellant (mainly) as well as bipropellant thrusters, generally results in the total consumption (decomposition/combustion) of hydrazine, just like the hot firing in space vehicles (see above under 1.).

The test specimen is a mechanical rig which contains some measurement sensors, short connection pipes/flexibles, electrical connectors for the thruster-valve and the thruster itself, i.e. complete thruster or thruster assembly (feedline, valve, injector/catalyst chamber, thrust chamber, nozzle).

Hot firing is performed mainly *under vacuum conditions* in a vacuum test cell. Only for dedicated test purposes a *sea level testing* may be performed. Sea level testing uses in principle the same set-up as for the vacuum testing, just the vacuum installation (cell, piping, pumps) is missing.[43]

The hydrazine supply system is designed as a closed system consisting of the following stages: Pressure drum - piping - control valves – test specimen. Unlike loading into propellant tanks of space vehicles, supply of hydrazine into the test specimen is an integral part of the hot firing testing operation. Ground facility

[41] Any residues are collected and sent to an authorised waste treatment plant, see 11. of this Annex.
[42] See previous footnote.
[43] Sea level testing using hydrazine is currently not performed in EU, but may be conducted again in the future under closed system conditions as defined in this Position Paper.

tanks are simple pressure fed cylinders (whereas flight tanks can have a membrane, pressure fed or bladder designs), which are part of the ground test facility; they are designed and certified in accordance with the IMDG/ADR/RID rules or applicable pressure system safety regulations.

The different purposes of thruster testing are summarized in the following table.

Purposes of hot firing test of thrusters on ground

Form of thruster testing	Description of purpose
Research and development testing	Testing may relate to: new/modified and non-production thruster engine, fundamental investigations and principles (injector concepts, cooling concepts, new materials, etc.), multiple configurations and test protocols to determine new future product designs
Qualification testing	Testing of a thruster to demonstrate performance and lifetime abilities of a production class of engine. Thruster is subjected to various conditions to simulate expected operational limits in space. Hot firing has to show that the thruster will withstand operation conditions out of the acceptance specifications (margin tests).
Acceptance testing	Testing of a production engine to demonstrate functionality and acceptable performance levels for customer approval requirements. Testing includes standard on/off sequenced test firing to meet quality/customer specifications and to demonstrate correct workmanship.

From an exposure point of view there is no difference between the different forms of thruster testing. Under normal conditions and using standard controls, no worker exposures or releases to the atmosphere would occur because of the decomposition or combustion process during hot firing.

- This applies notably to the main case of *testing in vacuum test cells*. Under vacuum the exhaust will be collected in a closed vacuum system and sucked out by mechanical pumps. The exhaust gas will be treated with a scrubber or gas washer equipment. Thus any small amounts of contaminated exhausts from the hot firing remain in a closed system. The contamination of the vacuum test cells is checked permanently by gas monitors. In case of an unexpected contamination of the vacuum test cell the equipment is cleaned by water and the water or cleaning tools are handled as contaminated waste.
- In case of *sea level testing* using hydrazine as part of a bi-propellant system there is no release of hydrazine to the environment as it is fully consumed due to the oxidiser lead used for such hot fire tests.

Safety procedures are applied for all working steps and general test site safety procedures are in place. All hot firing is performed at dedicated test sites with dedicated licenses and restricted access under stringent safety conditions and governmental supervision.

Workers are highly skilled and regularly trained. Workplace and workers are monitored by sensors to detect hydrazine leakage. Workers, who could potentially be exposed to hydrazine, always wear special personal safety equipment.

6. Filling into containers, transfer from one container to another ("transfilling")

Hydrazine is transferred by pressurisation from one transport container (pressure drum, cylinder or other receptacle which can be used for transportation) to another ("transfilling"). This is necessary to deliver the right quantity to the customer.

The final transfer from pressure drum to propellant tank for flight ("loading") has already been addressed above under 2.

During pressurization/de-pressurization the gases will be dissolved by gas washer and highly efficient neutralization equipment. The remaining contaminated solution will be disposed (waste) and treated in a neutralization plant.

Workers are highly skilled and regularly trained. Workplace and workers are monitored by gas detectors. Workers always wear special personal safety equipment like gasmask and protective clothes as precaution.

7. Pressurization with inert gases (N_2, He)

After filling of the drums with hydrazine they are pressurised by inert gases for storage and transport to customers or the launch site. The overpressure prevents any particle, oxygen or humidity contaminating the hydrazine.

The pressurization step can also be regarded as one (final) stage of the transfilling use described above under 6.

During pressurization/de-pressurization the gases will be dissolved by gas washer and highly efficient neutralization equipment. The remaining contaminated solution will be disposed (waste) and treated in a neutralization plant.

Workplace and workers are monitored by gas detectors. Workers are highly skilled and always wear special personal safety equipment like gasmask and protective clothes as precaution.

8. Storage, keeping

Hydrazine is stored in containers (pressure drums, transfer tanks, etc.) in dedicated areas under controlled conditions, with no likelihood of exposure. Containers are certified according to transport regulations (IMDG, RID, ADR) or applicable pressure system safety regulations. Periodic inspections of the containers as well as pressure & leak tightness check are carried out regularly.

9. Purification of hydrazine anhydrous

End users of hydrazine anhydrous for hot firing in space vehicles require high purity grade, which has hydrazine content above 99%.[44] Purification of hydrazine anhydrous to a higher grade for final hot firing purposes may therefore be necessary. However, the imported hydrazine anhydrous can already be used as fuel if the required quality is sufficient (e.g. so called "monograde").

[44] See ECHA, Annex XV dossier for Hydrazine, February 2011, p. 21.

The purification is based on a physical "cleaning" process and is not manufacture (chemical synthesis), i.e. the substance hydrazine is not chemically modified.

Purification is carried out into certified containers through gastight tubes. Neither exposure of workers nor releases to the environment occur during purification.

Workplace and workers are monitored by hydrazine detectors. Workers always wear special personal safety equipment.

10. Purification of hydrazine hydrate

To date anhydrous hydrazine has been imported from non-EEA manufacturers. However, as access to space is strategic for the EU, sourcing hydrazine from outside of EEA is a major concern; this supply is a weakness for European space programmes. Therefore secure sourcing of hydrazine anhydrous on the European market by means of obtaining it in EEA from hydrazine hydrate sourced from EU manufacturers by purification for space propellant use only is being considered. Then purification of non-fuel-grade hydrazine hydrate to obtain fuel-grade hydrazine anhydrous would be carried out by EEA-based companies.

The starting material is hydrazine hydrate, which cannot be used as space propellant without further purification. Purification means separation of hydrazine and water through distillation and crystallisation to generate fuel-grade high purity hydrazine anhydrous. Similarly to purification of hydrazine anhydrous, purification of hydrazine hydrate is basically a physical "cleaning" process and is not a manufacture (chemical synthesis), i.e. the substance hydrazine is not chemically modified.

All handling and purification steps with hydrazine are foreseen to be done in closed systems (no release to air, soil and water, no contact with the substance for the users). Workers will be highly skilled;[45] they will be protected by choosing the right protective clothing and equipment and releases to air will be excluded through use of proper gas cleaning systems. The working environment will be monitored by sensors.

11. Decontamination, cleaning of equipment and disposal of waste

Decontamination, cleaning of equipment and waste disposal are mandatory process steps associated with the respective main handling steps of hydrazine, which are described above. They can therefore be regarded as integral (final) stage of the respective main handling steps of hydrazine described above.

Equipment to be cleaned includes e.g. the Fuelling Ground Support Equipment [FGSE], containers, test thrusters, personal protective equipment, cleaning items (such as cloths/rags) or Draeger tubes used for hydrazine detection.

The main activities in this respect include:

- Waste air treatment / gas washer equipment connected to the space vehicle filling facility or ground test facility, which serve to remove any residual vapour of hydrazine and notably include dedicated neutralization systems.
- Flushing of equipment or pipework with water or other substances; contaminated water/other substance will be disposed (waste) or treated in a neutralization plant. Equipment is flushed with water in a sealed condition before being dismantled.

[45] Companies intending purification of hydrazine hydrate are already today manufacturers of MMH (monomethylhydrazine) or downstream users of hydrazine (anhydrous).

- Following hot firing testing of thrusters standard cleaning / decontamination protocols for the rocket engine are followed.
- Potential residuals of hydrazine are normally classified as waste and no further usage applies. Such residuals are collected and disposed (waste) under certified control.

Workplace and workers are monitored by sensors to detect hydrazine leakage. Workers always wear special personal safety equipment.

Annex 2 to Position Paper

Article determination for hot firing in space vehicles according to ECHA guidance on substances in articles

This Annex details the determination of an article with an integral substance for the hot firing in space vehicles according to the Section 2.4 of the ECHA *guidance on requirements for substances in articles*.[46]

According to REACH Article 3(3) *article means an object which during production is given a special shape, surface or design which determines its function to a greater degree than does its chemical composition;*

Uses of articles are not uses in the sense of REACH Article 3(24) and are therefore not subject to authorisation under REACH. The authorisation requirement only applies to the incorporation of the substance into an article (or "production of an article", see REACH Article 3(24)).

Hence, the authorisation requirement does not apply to the final use of hydrazine as a propellant in space vehicles, if the hydrazine is regarded as an integral substance within an article (satellite, probe or launcher), as opposed to a combination of an article (functioning as a container or a carrier material) and a substance. The borderline between these two cases should be determined according to the article determination approach suggested in the ECHA guidance on requirements for substances in articles.[47]

Article determination according to the ECHA guidance on substances in articles:

Step 1*: Define the function of the object in line with section 2.1.* [of ECHA guidance on substances in articles] *The term "function" in the article definition should be interpreted as meaning the basic principle determining the use of the object rather than the degree of technical sophistication determining the quality of the result. In this sense, it may be helpful to look at the result of using an object and pay less attention to the quality of the result. For example, the basic principle behind a printer cartridge is to bring ink onto paper. A higher degree of technical sophistication of the object "printer cartridge" may improve the functioning and the quality of the result but it does not change the function as such.*

The object in question is the space vehicle as a whole, not the fuel tank as this is an integral part of the space vehicle.[48]

The function, i.e. basic principle determining the use of the *space vehicle*, is *to move and transport technical equipment (payload)*. To this end *hydrazine* propellant serves as the *energy source to generate thrust.* Hydrazine is consumed internally within the space vehicle and no hydrazine is released to the outside.

Step 2*: In many cases applying the REACH definition of an article is straightforward. The decision on whether an object is an article or not can then directly be made by comparing the importance of physical and chemical characteristics for achieving the object's function. If you can unambiguously conclude that the shape, surface or design of the object is more relevant for the function than its chemical composition, the object is an article. If the shape, surface or design is of equal or less importance than the chemical composition, it is a substance or mixture.*

[46] Version 2, April 2011.
[47] See ECHA, Guidance on requirements for substances in articles, Version 2, April 2011, Section 2.4.
[48] This is also in line with the interpretation represented by ECHA, the Commission and the majority of EU Member States in the context of the calculation of the 0.1 % w/w concentration threshold for SVHC in articles, which should be done in their view based on the complex article as produced or imported, and not based on its homogeneous materials or parts.

At a first glance, it could be argued that a space vehicle is unambiguously an article, so the assessment could stop already here. However, such a conclusion appears to be premature, as it would completely ignore the concept of a "substance in a container" which the ECHA substances in articles guidance addresses in-depth for several examples of objects containing a liquid that could be physically separated from it. Such a case is given here with hydrazine propellant filled in the tank of the space vehicle. Therefore, the assessment should continue.

If it is not possible to unambiguously conclude whether the object fulfils the REACH definition of an article or not, a deeper assessment is needed; for this proceed with step 3.

Step 3: *Determine if the object, which may be constructed in a very simple or highly sophisticated manner, contains a substance or mixture that can be physically separated from the object (e.g. by pouring or wringing out). The substance or mixture in question, which can be solid, liquid or gaseous, can be enclosed in the object (like e.g. the liquid in a thermometer or the aerosol in a spray can), or the object can carry it on its surface (like e.g. a wet cleaning wipe).*
If this applies to the object, proceed with step 4, [...].

As already indicated above, the object *space vehicle* contains the substance hydrazine that can be physically separated from the space vehicle by means of emptying the propellant tank.
As the answer to step 3 is positive, the assessment should continue with step 4.

Step 4: *For determining whether the chemical content of the object is an integral part thereof (and therefore the object as a whole is an article as defined under REACH) or if it is a substance/mixture for which the rest of the object functions as a container or carrier material, the following indicative questions should be answered:*
Question 4a: If the substance/mixture were to be removed or separated from the object and used independently from it, would the substance/mixture still be capable in principle (though perhaps without convenience or sophistication) of carrying out the function defined under step 1?
Question 4b: Does the object act mainly (i.e. according to the function defined under step 1) as a container or carrier for release or controlled delivery of the substance/mixture or its reaction products?
Question 4c: Is the substance/mixture consumed (i.e. used up e.g. due to a chemical or physical modification) or eliminated (i.e. released from the object) during the use phase of the object, thereby rendering the object useless and leading to the end of its service life?

If you can answer these questions predominantly with yes (i.e. 2 of 3) rather than no, then the object should be regarded as a combination of an article (functioning as a container or a carrier material) and a substance/mixture.

Answer to Question 4a: **NO** - If the hydrazine was to be removed or separated from the space vehicle and used independently from it, the hydrazine would not be capable of moving it, as the hydrazine could not be consumed as an energy source within the propulsion system. Hydrazine can only execute its function in a propulsion system specifically tailored to it in terms of design and materials used.

Answer to Question 4b: **NO** – The object *space vehicle* does not act as a container or carrier for release or controlled delivery of hydrazine or its reactions products (the hot gas/exhausts), but its main function is to move/transport technical equipment (payload). The movement is achieved by the thrust generated through the hot firing of hydrazine. Hydrazine is not released or delivered by the space vehicle and is consumed internally only.

Answer to Question 4c: **YES/NO** – Indeed hydrazine is consumed within the space vehicle through hot firing during its use phase. In case of a *satellite*, the end of its service life is also primarily due to the fact that it is running out of the fuel (hydrazine) needed to maintain its orbit (geostationary orbit for example) or its required attitude on orbit (for solar panel or antenna orientations for example). However, the actual end of a satellite's service life is initiated at a time when hydrazine reserves are still in the tank allowing either to free the slot in orbit (transfer to a graveyard orbit) or to de-orbit (descent of the satellite). In case of a *launcher*, the hydrazine loading shall guarantee the mission fulfilment (including transfer to a graveyard orbit or de-orbiting) so that residuals stay inside the tanks after the use phase. In all cases, final hydrazine residuals are released into space on the graveyard orbit or just before re-entry into the earth's atmosphere to prevent any subsequent explosion. Therefore, the answer to this question is not unambiguously yes.

Even if the answer to question 4c was yes, the questions 4a-c cannot be predominantly answered with yes. This indicates that the space vehicle as a whole, including the hydrazine as a component, should be considered as an article. Therefore, the assessment should proceed with step 5.

Step 5: *If the answers to the indicative questions under step 4 are mostly no, you should use the following questions to cross-check whether the object as a whole should indeed be considered as an article and not as a combination of an article (functioning as a container or a carrier material) and a substance/mixture.*
Question 5a: If the substance/mixture were to be removed or separated from the object, would the object be unable to fulfil its intended purpose?
Question 5b: Is the main purpose of the object other than to deliver the substance/mixture or its reaction products?
Question 5c: Is the object normally discarded with the substance/mixture at the end of its service life, i.e. at disposal?
If you can answer these questions with yes rather than no, then the function of the object is likely to be determined rather by the physical properties shape, surface and design, than by the chemical composition. The object is then regarded as an article with an integral substance/mixture (i.e. the substance/mixture forms an integral part of the article).

Answer to Question 5a: **YES** – If the hydrazine was removed or separated from the space vehicle, the space vehicle would be unable to fulfil its intended purpose (movement and transport of equipment).

Answer to Question 5b: **YES** – The purpose of the space vehicle is not to deliver the hydrazine or its reaction products (exhausts), but to move and transport technical equipment.

Answer to Question 5c: **YES** – Even if the useful propellant contribution is consumed and considered exhausted at end of life, still some non-usable propellants remain inside the tanks and the feed system. Those residuals are not accessible for useful usage due to technical reasons. Since being unavoidable they remain present in all cases and will be disposed with the space vehicle at end of life.

The questions 5a-c can be predominantly answered with Yes. This confirms the conclusion reached based on questions 4a-c that the space vehicle as a whole should be considered as an article, including the hydrazine as an integral part.

It should also be noted that hot firing of a propellant in space vehicles is not comparable to the case of *fireworks*, where the ECHA guidance sees a substance/mixture in containers.[49] The function of fireworks is to explode and make light effects. If the chemicals were removed, they could still explode and make light effects. The function of the entire object is to bring the substances or their reaction products into the air, thus to deliver them.[50] By contrast, the main function of the space vehicle is not to bring hydrazine into the air, but it is rather the function of the hydrazine to ensure the correct flight of the space vehicle. Hence, the function of the space vehicle leads.

[49] See ECHA, Guidance on requirements for substances in articles, Version 2, April 2011, Appendix 1, Table 3, p. 35.
[50] See previous Footnote.

A similar case to hydrazine propellant is rather the *electrolyte in a battery*. Battery electrolytes can perform their function only within the battery with its specific design and are not released from the battery. Therefore, the ECHA guidance on substances in articles concludes, that a battery is an article with an integral substance / mixture.[51]

The critical consequences of this article classification are:

1. **The hot firing of hydrazine in space vehicles is not subject to authorisation.**
2. **The uses of hydrazine *as a substance* end with its loading into the propellant tank.**

[51] See ECHA, Guidance on requirements for substances in articles, Version 2, April 2011, Appendix 1, Tables 2, 4 and 5.