

Goldfish Project

Feasibility Study - Final Report



GOLDFISH

The first solar-powered passenger submarine in the world
shown against the unique backdrop of the Swiss Alps

Thun, May 11, 2008

Executive summary

Mobility – renewable energy – water. BKW and BLS – two companies with a rich and long tradition – both wish to make their own contribution to these globally interesting subjects. The GOLDFISH Project was born out of the desire to create an innovative, sustainable project unique in the world.

It is BKW and BLS's intention that the GOLDFISH Project should demonstrate their commitment to sustainable solutions and the technical expertise they have at their disposal.

The feasibility study showed that it is possible a) to operate a submarine on Lake Thun and b) to supply this submarine with electrical energy from a floating solar platform. Any doubts concerning technology and government requirements have been dispelled.

The operational concept forming the basis of the feasibility study envisages a shuttle which ferries passengers out to the solar platform and takes them back to the shore after the submarine dive. The solar platform constitutes a power plant as well as a boarding station for the submarine. Other activities on-site on the platform – in particular those involving another cooperation partner – are possible and indeed desirable.

The submarine technology is determined to a large extent by the provisions laid down by the technical regulatory authorities. These provisions ensure a very high standard of safety and have a major influence on design.

An initial plan for the solar platform involves a central element covered by a high-pitched tent-like structure around which five satellites containing solar panels are arranged. The entire platform remains in situ automatically. The platform can be constructed using already existing technology.

All the necessary permits have been obtained within the framework of the rules and regulations currently applicable. Officially, the submarine and platform are classified as ships. By adopting a constructive interpretation of the specifications, the process can be swiftly put into action.

In October 2007 capital expenditure volume was estimated at CHF 10 million, a figure which has proved to be realistic. Annual operating costs are heavily dependent on the operational concept and lie in the region of between one and two million CHF.

More detailed examination has confirmed our original estimates, and we have discovered nothing that might present insurmountable obstacles as far as the technology and legal permits are concerned. We are confident that with appropriate funding this visionary plan can be successfully adopted for swimming, diving and enjoyment.

On behalf of the project team

Matthias Zellweger

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The feasibility study remit

BKW FMB Energy Ltd. and BLS AG intend to develop together and with other partners a floating solar platform and a submarine as a tourist attraction. The roles to be fulfilled by the other partners have yet to be defined.

To pinpoint the opportunities and restrictions inherent in this concept, they appointed Matthias Zellweger, as GOLDFISCH project manager, with the task of carrying out a feasibility study.

The purpose of this study is to answer fundamental questions up front, thus ensuring that any implementation project can be planned and realised in a joined-up approach. In particular, this initial groundwork is intended to identify possible risks inherent in the project.

In addition to resolving technical and formal issues, the size of the initial financial investment and operating costs should also be defined.

The formulation of operational models with accompanying business plans does not come within the scope of the feasibility study. The operational model depends largely on the interests of the other partners; this work will therefore be carried out once the basic specifications have been clarified.

Feasibility issues were divided into the following categories:

Submarine

- Functions, dimensions
- Requirements made of operation
- Safety
- Costs

Solar platform

- Dimensions, design
- Technology
- Platform mobility
- Expansions, modifications
- Costs

Shuttle

- Costs, deadlines, technology

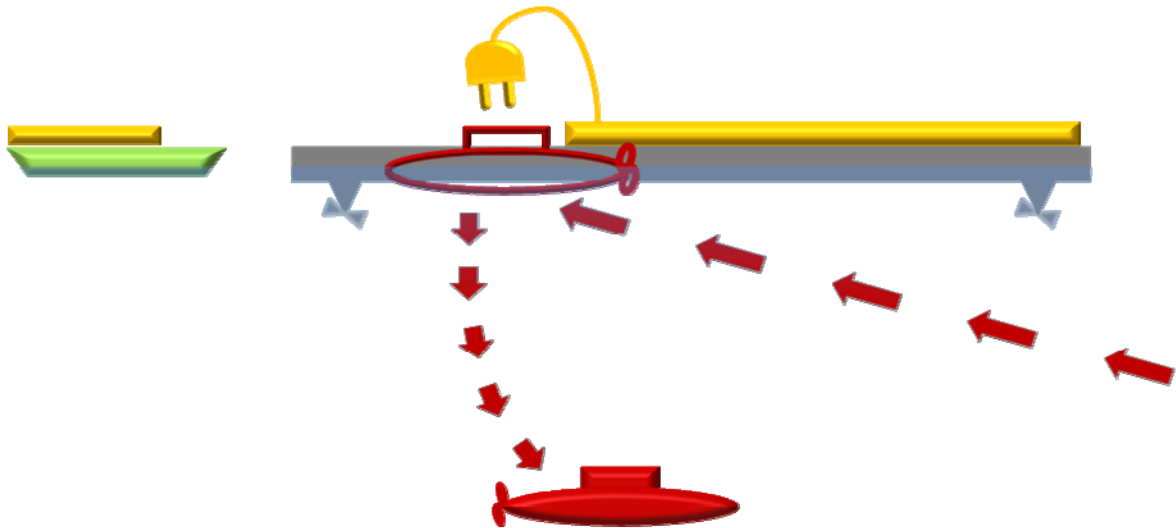
Permits

- Submarine
- Solar platform

A. The overall project

A.1. Functionality, steps involved

The customers/passengers should enjoy an experience at the starting point, on the platform and of course during their trip in the submarine.



A shuttle (green) ferries the passengers from the starting point on the shore to the platform (grey) out on the lake. They transfer to and from the submarine (red) on the platform. After the dive the passengers are ferried back to the starting point.

Of course the submarine can also be deployed from a suitable point onshore, in which case it must be borne in mind that the submarine moves slowly in a horizontal plane and will therefore consume more energy than a simple, streamlined ferry. The submarine also has a significantly greater draft.

Hence the point from which the submarine starts should be made dependent on the depths to which it will be diving. The floating, mobile platform offers a very good solution to this conceptual requirement.

A.2. Model assumptions

From a technical point of view the submarine could be deployed on a daily basis throughout the entire year, with the exception of a two-week break for maintenance. However, for the purpose of all the considerations forming part of this study, we have based our assumptions on 100 passengers on 100 days per year – the equivalent of four trips with a medium-sized submarine. Depending on the type of service being offered, the price of tickets can vary between CHF 70.- and 200.-.

The size of the ferry is directly dependent on the submarine's capacity. If additional attractions are on offer on the platform, it may be necessary to raise transport capacity requirements and frequency of operation. A conventional or solar-powered ship can be deployed as the ferry.

For the purposes of the feasibility study we assumed that approx. 60 passengers were on board the ferry at any one time.

A.3. Communicating the project – special interest points

Uniqueness

The first submarine powered by renewable energy in the world. The only opportunity in the whole of Europe to dive in a submarine as a tourist in inland waterways.

GOLDFISCH is quite obviously not a “copy cat” project.

Technology - Tourism

The platform with the submarine can be communicated as a tourist attraction as well as a high-level technical challenge.

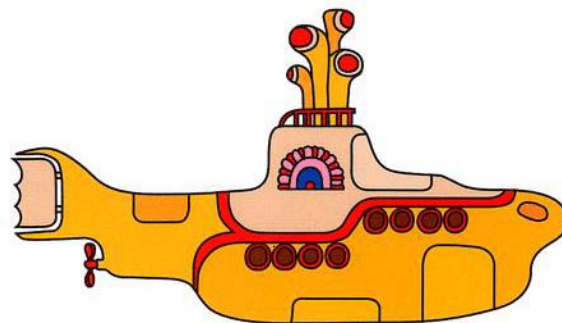
Attraction and interest

A “submarine” is a concept no-one can ignore. Images from history, “20,000 Leagues Under the Sea”, “The Boat”, “Yellow Submarine”, etc., trigger a variety of strong, emotional associations.

For this reason, the interest in a submarine on / in Lake Thun could focus far more on the actual experience rather than on what can actually be done with a submarine and what one sees in the process.

The highpoints on Lake Thun need to be of a quite different nature than (e.g.) in the Caribbean.

The interest potential of the platform can also be leveraged. Describing the platform as nothing more than a necessary technical accessory to the submarine would be inefficient and diminish the quality of the project. Emphasis should not be placed on the submarine, but on the concept of “Solar energy allows us to travel and dive in a submarine”.



Messages

The project message can be summed up in three topics:

a) Experience, tourist attraction

Here, people can experience a new adventure, whether it is the arrival, the crossing, the time on the platform, or the submarine trip. There will be new things to see, memories to take home and experiences to talk about. People will discuss whether the experience would be different elsewhere on the lake, during different weather conditions, or in another season. Maybe visitors will want to take another dive with their grandchildren, with their friends, or just on their own. Or maybe people may even be invited to a “Captain Nemo Dinner” in the murky depths?

b) Environment, technology, confidence

Solar technology is perceived as being a technology of the future and as environmentally friendly. The technologies intended for the project can also be reliably implemented. Experienced technicians and water sports enthusiasts with many years experience have some difficulty in understanding the excitement passengers will experience when they set foot on a gently moving platform and what reservations they may have about a submarine of this kind. When the boat travels with obviously adequate power reserves and everything remains dry – as is anticipated –, the experience can have a lasting effect on instilling confidence in new technology.

c) Embracing a new future together

There’s no shortage of ideas. We know how everything works – now all we need is someone to actually put it into practice. In the Goldfish Project, the partners can show their mettle as movers and shakers. They believe in innovation; they believe in the future.

The form of the cooperation is new, as well as the content, with the project involving a cross-section of companies from a wide range of industries.

Platforms

As the project becomes better known to the general public, it becomes a more attractive proposition for potential partners. As long as no decision has been made about who the other partners will be, it remains impossible to define precisely how the project should be implemented. Accordingly, communication also remains impossible.

The opportunity to exhibit the project under the heading of “new renewable energy” at the Swiss Pavilion at the world expo in Zaragoza is interesting for two reasons. First, it encourages potential partners to leverage this presence. Second, the project can be displayed for the benefit of a broad general public in a prominent setting and for relatively little outlay.

Critical elements

Careful thought needs to be invested in communication. Prudence is called for where certain elements are concerned. The following list of potential hazards is by no means complete, and it is without doubt wise to update it on an ongoing basis.

Visual communication

- Images of Caribbean fish: The public's attention is directed towards a visual experience which is not available – it takes a great deal of effort to make up for disappointment.

Environment

- Solar energy straight into the submarine: In accordance with the idea behind the project, the platform feeds energy into the network, and the submarine is recharged with night energy from the grid – an equation which makes sense from an ecological point of view too. It is important for the whole picture to be conveyed to a broad general public in a way which can easily be understood, otherwise people will treat it as if we are trying to pull the wool over their eyes.

- Powering the submarine: Powered purely by electricity, with solar energy, hence 100% environmentally friendly. For practical and safety reasons the boat will probably be fitted out with an additional 100 kW diesel engine.

A.4. Costs

Initial costs, capital expenditure

Submarine procurement, built in Florida		
16 passengers	3,800,000.-	
24 passengers	4,500,000.-	
36 passengers	5,300,000.-	
Transport to Lake Thun	150,000.-	
Commissioning	350,000.-	
Reserves for technology and special solutions	400,000.-	
<hr/>		
Total submarine (24 passengers)		5,400,000.-
Infrastructure modification		50,000.-
Ferry		750,000.-
Solar platform		3,600,000.-
Reserves for technology		200,000.-
	Total	10,000,000.-
<hr/>		
Project organisation		500,000.-

Operating costs

(without cost of capital)

Submarine:		
Personnel (200% + 100 days 200%)	550,000.-	
Overheads	100,000.-	
Infrastructure	50,000.-	
Maintenance and ABS inspections	100,000.-	
Insurance	150,000.-	
Energy, compressed air, oxygen	20,000.-	
<hr/>		
Total submarine		970,000.-
Ferry service (100 days 200%)		150,000.-
Solar platform		250,000.-
	Total per year	1,470,000.-

Other measures

Conclusion of planning, including obtaining permits	750,000.-
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A.5. Team for overall project

Matthias Zellweger	Project Manager
Dr. Jakob Vollenweider	Representative of BKW FMB Energy Ltd.
Michael Lüthi	Representative of BLS AG navigation

B. Permits

B.1. Results

According to inland navigation regulations, the solar platform and the submarine are defined as “ships”. This obviates the need for special procedures, depriving any critics of the project of the opportunity to block it for basic formal reasons.

The many conversations held with organisations and official bodies revealed that there are no “killer” criteria or fundamental negative criteria blocking the way forward.

A constructive interpretation of the specifications and regulations makes work on the project considerably easier. It is therefore important that the official bodies should receive the best possible support in their work.

We also took note of the concerns expressed by various interest groups, especially those that rely on fishing for their livelihood. Early cooperation would mean all parties would reap benefits.

Platform

- The process for granting permits is overseen by the Cantonal Water and Shipping Authority of Berne canton.
- The “ship’s permit” is granted on the basis of a report detailing conformity with the variously applicable laws (inland navigation and shipbuilding laws, AB-SBV).

Submarine

- The process for granting permits is overseen by the Cantonal Water and Shipping Authority of Berne canton.
- The passenger service vehicle permit is issued by the public transport department.
- A licence is not required – “non-scheduled services” as they are referred to, are at issue here (Art. 7 VPK; SR744.11).
- The permit is granted on the basis of two reports: a) report made by an external classification society (e.g. American Bureau of Shipping ABS) b) declaration of conformity with relevant legislation.

The next steps

- Submission of an implementation project.
- The Water and Shipping Authority of Berne canton is responsible for the coordination and implementation of the process for granting permits. During the processing procedure or when the final project has been submitted, the authority decides on which offices and organisations to inform and include.

B.2. Departments contacted

List of government departments and persons to whom a project presentation was made in person in the period from November 1, 2007 to April 30, 2008:

- Mr Righetti, |BAFU – Federal Transport Office
- Mr Lüthi | Office for Public Transport in Berne canton
- Mr Perrottet | Water and Shipping Authority of Berne canton
- Ms. Knecht | IMPULS AG – Forestry Countryside Natural Hazards
- Mr Kratzenberg | Federal Transport Office
- Mr Thelin | Department for Countryside and Infrastructure, UVEK
- Ms. Hermann | Head of Department for Passenger Transport, UVEK
- Mr Wyttenbach | Governor of Thun
- Mr Sulzer | Water police
- Mr Iseli | Water police - Operations
- Messrs. Knutti and Schmid | Water police - Specialist department
- Mr Stoffel |Police responsible for hydraulic structures
- Mr Spycher | District senior engineer
- Mr Hadorn | Police stationed in Bernese highland region
- Mr Flühmann | General secretariat VBS, Environment
- Mr Baumann | AGR Landscape aesthetics
- Mr Mathieu | Armasuisse VBS, Kamibes diving group
- Mr Tschan | Civil engineering inspectorate, Thun
- Mr Haueter | Submarine owner / Operator in Spiez
- Messrs. Rieder and Lehmann | Därligen fish farm
- Mr Klopfenstein | Professional fisherman
- Ms. Wagner | Pro Natura
- Mr Rösti | Office for Countryside and Nature in Berne canton, nature conservancy inspectorate

- Mr Müller | Lake Thun Fisheries Inspectorate

B.3. Clarification of permits

Matthias Zellweger

Project Manager

C. Solar platform

C.1. Overall design concept

The idea behind the Goldfish Project is that visitors gain access to a solar platform via a ship, with the platform functioning both as a solar power plant and as the starting point for submarine trips. The energy produced by the solar plant should be sufficient to power submarine dives and ensure the safe operation of the platform. Particular importance is attached to fully computerised platform positioning.

Mounted on floats, the platform should meet the following technical requirements:

- It should be able to hold 60 passengers, with access for persons with special needs
- It should contain a docking point for the submarine
- It should contain a docking point for a small passenger ship
- It should meet all applicable statutory requirements (safety)

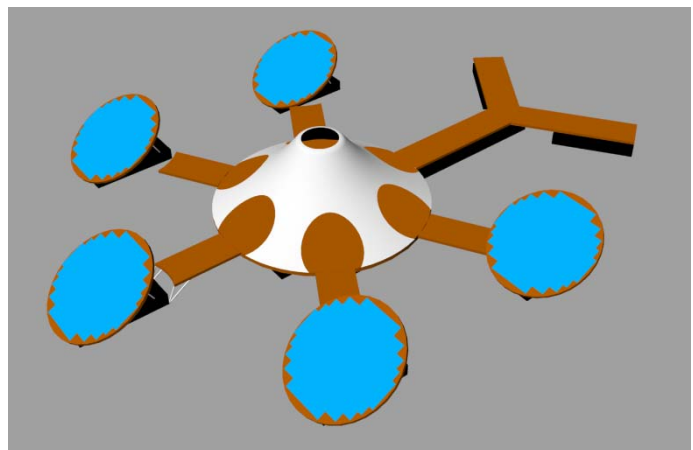
Other requirements made of the platform are:

- Clearly recognisable from the shore (publicity)
- Open architecture
- Solar roof should not be over-evident, but should be capable of changing (dynamic approach)

The overall design concept described here consists of the following elements:

- a) Main platform
- b) Satellite islands
- c) Docking pier
- d) Connecting piers

a/b/c floating on steel structures



C.2. General requirements

Permits

The authority with competence for issuing the operating permit (ship's licence) is the cantonal office for road transport and navigation. To obtain the licence, a technical acceptance procedure carried out by the competent authority must be accompanied by the presentation of a certificate governing aspects of the platform relevant to safety. This proves that the platform meets the legal requirements (stability, non-sinking characteristics, dynamic positioning, etc.). This certificate can be issued by a naval engineer. Shipbuilding regulations (AB-SBV) and the regulations governing inland navigation (BSV) provide the legal basis. No legal obstacles exist which might jeopardise the issuing of a permit for a platform of this type.

Stability

The stability of the main platform is assured by 13 water-tight chambers below deck. Assuming the platform is loaded with 60 passengers at a maximum density of 3.75 persons/m², the requirements as set out under AB-SBV are complied with.

The satellites weighing approx. 6.5 tonnes are inherently stable enough to allow them to withstand very strong winds. They are also joined to the main platform (weight: approx. 45 tonnes), thus ensuring additional stability.

No problems exist concerning the stability of the platform.

C.3. Design, dimensions, requirements

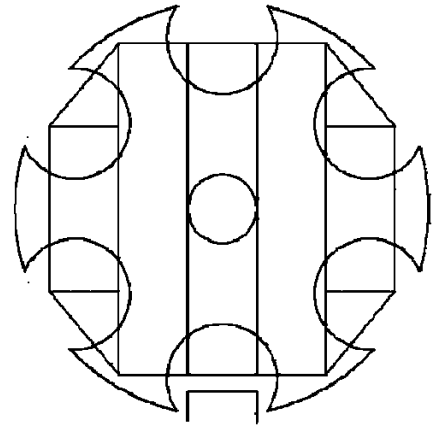
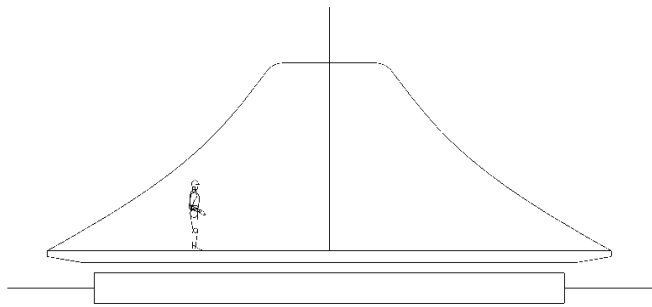
Main platform

The circular platform with a diameter of 15 metres consists of a base with a wooden deck. The piers on the platform are surrounded by a continuous guardrail containing a handrail and cables. The platform is covered by a high-pitched roof approx. 5m in height featuring a circular opening at the apex and elliptical openings on the sides.

In the basic version, the main platform is designed as an open area where visitors can move about, take photographs and find out about the platform and the dive they are about to embark on. The high-pitched roof provides protection against inclement weather as well as offering shade in the summer.

The float supporting the main platform consists of 3 large (12mx2.5mx0.8m) and two small (6mx2.5mx0.8m) steel structures. These floats are each inherently capable of floating and are subdivided into 3 or 2 elements (water-tight bulwarks). Each chamber has its own water level gauge and an individual bilge pump. Access for periodic inspection work is via a water-tight manhole on the upper side. The floating elements are bolted solidly together, but can be separated if required for transport purposes. The floats on the satellite islands and the docking pier have the same dimensions as those on the main platform. This modular design makes for ease of transport of the entire solar platform onshore (5 standard trucks).

Cross-section and plan of main platform:



The central float houses 8 battery boxes (each 48V 480 Ah/C5) and an engine room housing a diesel genset (150 kW) to meet energy requirements at peak times (winter storm) or when there is a total power failure.

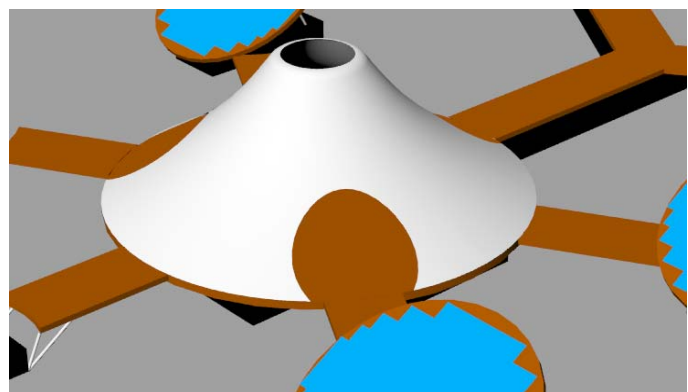
A central anchor weighing 100 kg with winch offers further protection against possible collision should the platform drift.

Two of the floats feature an electrical power unit (rigid shaft) each delivering 50 kW. As soon as the onboard computer calculates that in order for the structure to maintain its position more energy is required during high winds than can be obtained from the inclination of the platform's solar panels, the platform automatically turns into the wind so that the main power unit can operate against the wind.



Visitors' centre variant

If required, the main platform could be fitted out as a visitors' centre. The main requirements here would be for toilet facilities with access for those with special needs, and a small snack bar. Further additions are also possible and a small museum providing information about the project and the sponsors could also be included (similar to the "Soleil" information centre at the



Stade de Suisse in Berne). Half of the accesses would need to be closed off in order to create sufficient space on the platform. In this case, the non-accessed piers might be constructed in a lighter design version.

Satellite islands

A main pier connects the main platform with the solar ferry and the submarine.

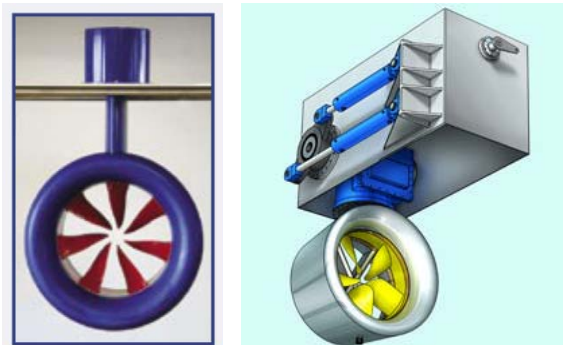
Five additional piers provide visitors with a room in which to walk about, and also connect the solar generators with the platform. Two emergency islands which are resistant to winter conditions are located at the end of the main platform. If required, these could be rolled into the water. A guardrail 1 metre in height surrounds the entire pier, thus preventing accidents to individuals.

The 5 solar generators each have a solar surface area covering 40m² which can be inclined up to 30° towards the sun, especially in winter. The onboard computer calculates the optimal angle of inclination at any given time and lowers the solar generators when a preset wind speed prevails, thus reducing air resistance.

In three of the five floats swinging electrical power units are housed – “azi pods”, as they are referred to – each delivering a maximum output of 15 kW. These propellers enable the dynamic positioning of the platform. They can be turned through 360° and are controlled directly from the onboard computer. The propellers are surrounded by a hydrodynamically optimised duct which serves to maximise thrust.



As an alternative to the azi pods, inline thrusters can also be used. With this system, the winding is located in the duct, creating very high thrust and a high level of efficiency (no shaft, no transmission).



This power unit also exists in a 360° rotating version (left) and in a rotating and tilting version (right).

Battery variants

Maintenance-free lead gel batteries are envisaged for the basis version. These must be replaced after approx. 5 years. They are, however, reliable and relatively inexpensive. Alternatively, lithium-ion batteries could be used. They are lighter in weight and more compact, but their application as a marine solution is still fairly restricted. The purchase price of these batteries is several times greater (17 times more expensive to purchase). As a third variant, zebra batteries were considered. These are already featured in various bus and submarine applications and are more interesting from the price point of view (approx. 2.5x more expensive than lead batteries). Their life cycle is also twice that of lead batteries. Overall, the choice between maintenance-free lead batteries and zebra batteries has a marginal effect on the global costs of the platform.



Zebra battery module (90Wh/kg)

Fuel cell variant

As an alternative to the battery solution, the use of a fuel cell as a power source was considered. The application of this energy principle would emphasise the innovative thinking behind the entire project. In addition, a small "museum" on the platform would introduce visitors to the technology while they waited.

A range of fuel cell types and electrolysators providing the necessary capacity are commercially available. Energy could be stored in the form of hydrogen.



The ferry could also be equipped with a fuel cell. (MW Line has already built 4 vessels powered by fuel cells.)

The fuel cell variant would require an additional investment of some CHF 1 million.

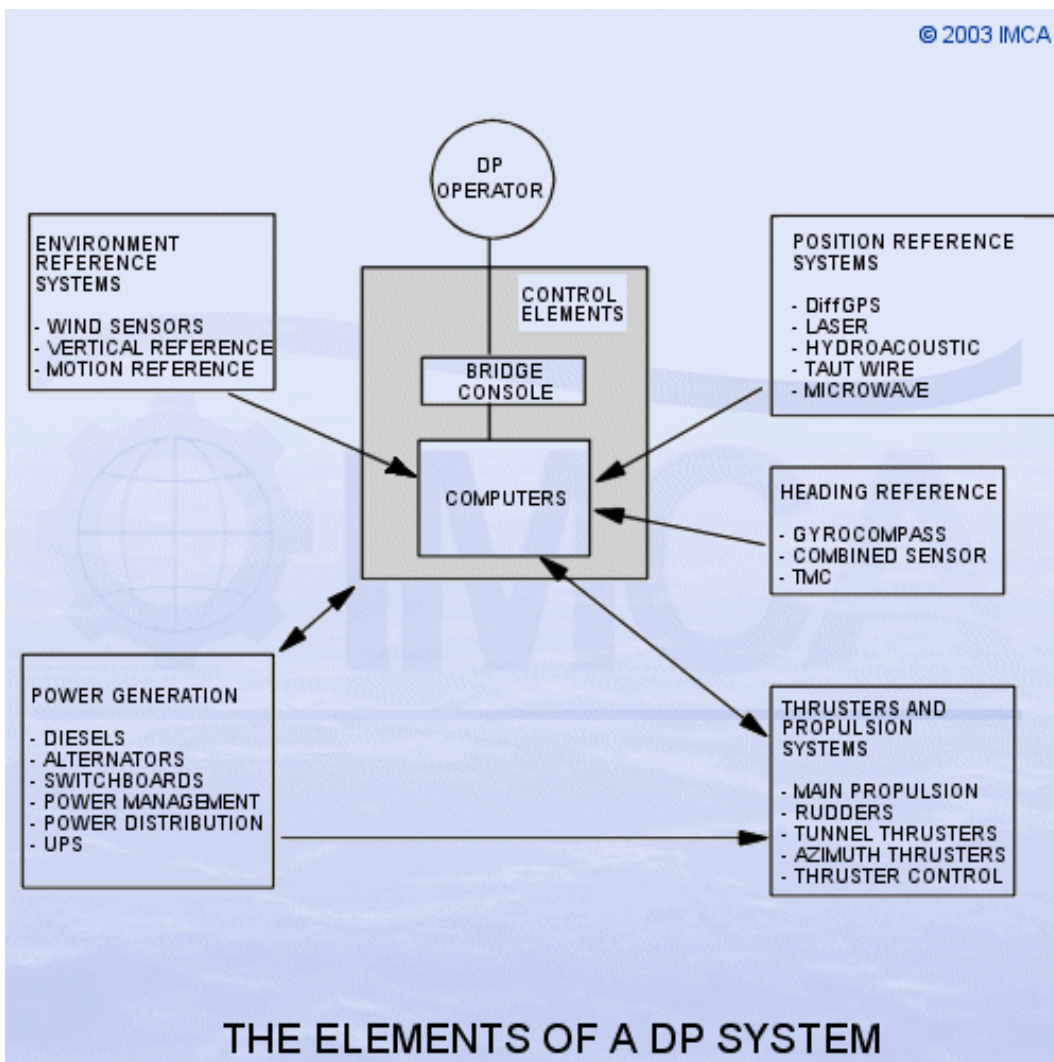
C.4. Dynamic positioning

As permanent anchoring of the solar platform is not possible, it is very important that its geographical position on the lake is monitored and guaranteed.

Dynamic positioning systems consist basically of the following components:

- One of the vessel's main power units
- 3-5 directional propellers at the vessel's extremities
- a central control unit (computer)
- instruments for measuring the wind, currents, position, energy reserves, etc.

Depending on safety requirements, certain parts of the system or entire power trains can be made redundant. Redundancy of this type compounds the complexity of the system as well as increasing the price. In the present case, a single redundancy system has been assumed. Operation of the diesel genset and lowering the anchor are controlled by the system fully automatically. It is also possible to intervene in the computer externally via the internet. Alarms can also be installed if required.



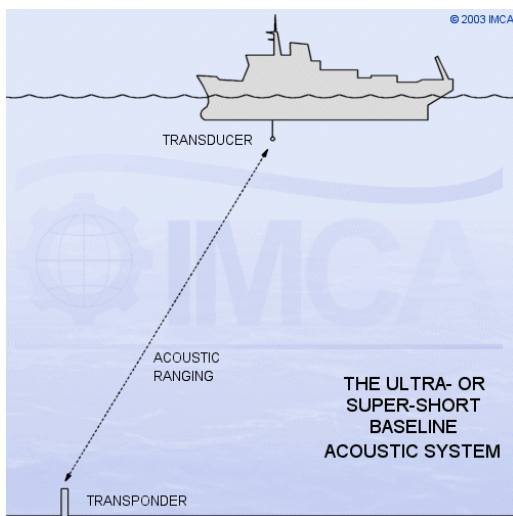
We suggest a differential GPS as the primary position transmitter, with either a DGPS fixed on another satellite or an underwater sonar system based on acoustic signals as the backup system.



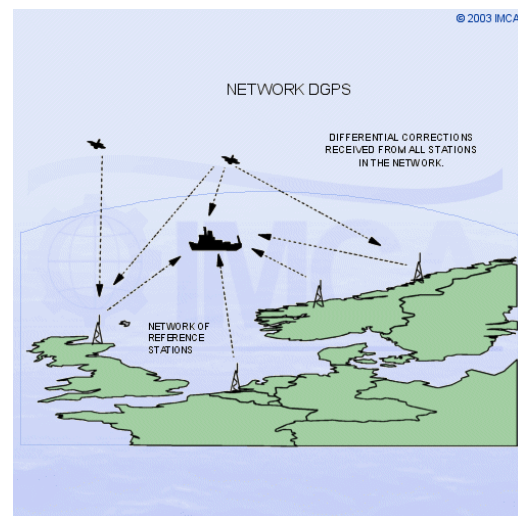
System control unit



Radio-controlled echo sounder

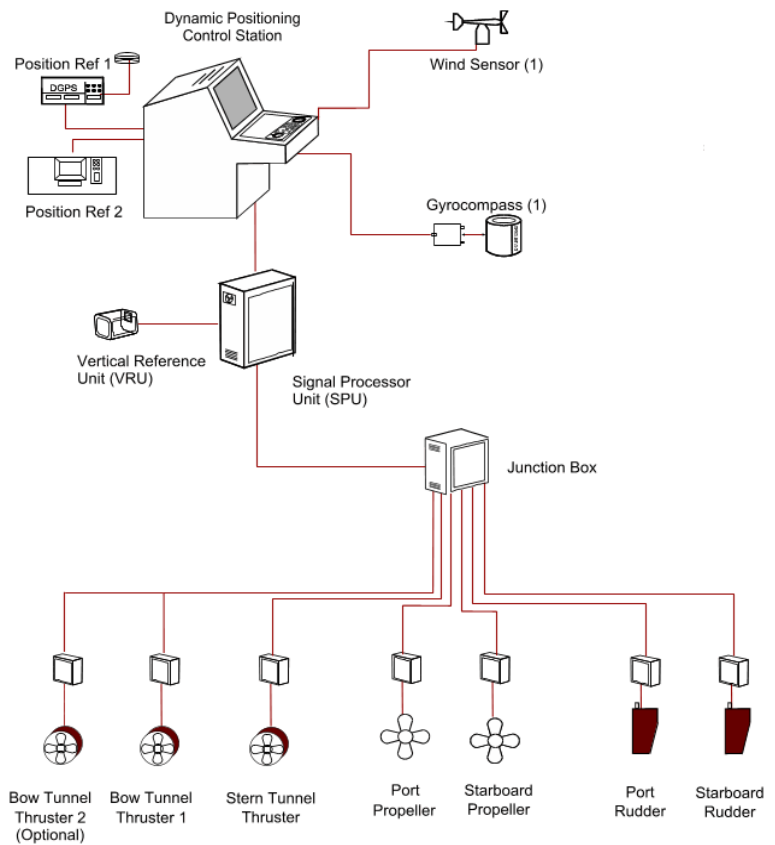


Positioning using echo sounder



Positioning using DGPS satellites

Outline of a DPS
with single redundancy:



C.5. Energy requirement

Submarine

The submarine is expected to be in service 100 days each year. Every day, it will make 4 trips carrying 25 passengers, with each trip lasting one hour. Assuming the trips will be conducted at a moderate speed, the submarine will require some 100 kWh of energy for each day it is in operation, resulting in an annual energy requirement of approx. 10,000 kWh.

Internal requirement for positioning

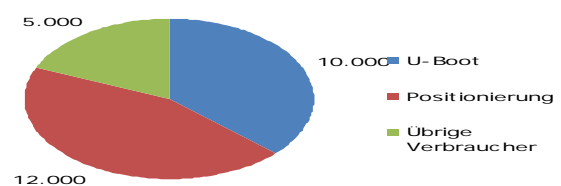
According to data provided by MW Line, a solar module surface area of approx. 100 m² is needed to provide the energy required for positioning the platform. This is the equivalent of a rated output of approx. 12 kW and an annual energy requirement of approx. 12,000 kWh.

Other consumers

The platform will also require a certain amount of energy to feed various onboard consumers. It can also be used to provide electricity for special events, with the technical devices needed to this end in place. As such applications do not occur very often, the amounts of energy required are minimal. For the purposes of calculation we have assumed an additional overall requirement of 5,000 kWh per year.

In total, the energy requirement is thus calculated to be 27,000 kWh per year.

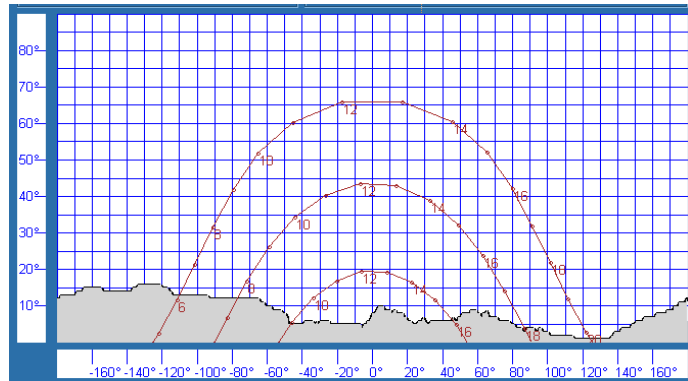
Energy consumption broken up into kWh/year



C.6. Solar technology concept

Available irradiation available

The solar platform site is ideal as far as the utilisation of solar energy is concerned. No shadows are cast near to the platform, and as the chart opposite shows, the distant horizon has minimal effect on irradiation.



H

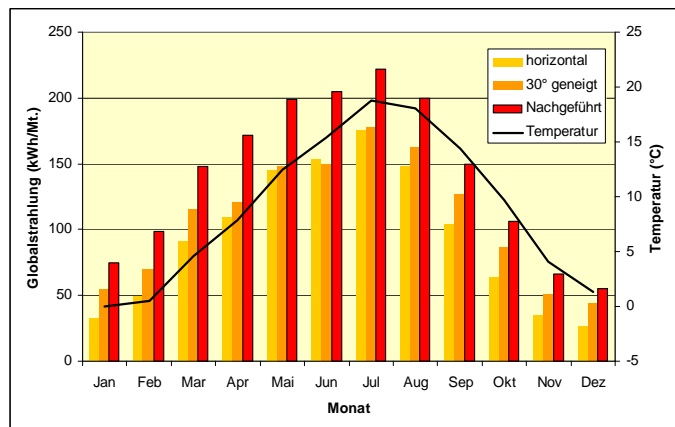
Effect of the horizon and sun's orbits on site at Lake Thun

The irradiation available on site has been calculated for three possible situations:

- horizontal module surface (flat surface or accessible module surface on the platform)
- module surface inclined by 30°, south-facing
- module surface constantly following path of sun (adjustable inclination and rotation of the platform)

The irradiation values calculated for one month are shown in Fig. 3, together with the mean ambient temperature.

The smallest output is obtained with the horizontal surface, variant a). Variant b) produces an annual output greater by 15% and variant c) greater by 50%. The figures for the winter months between November and February are more critical than the annual output; during this period; relative improvement is very important via optimal alignment.



Monthly irradiation and temperature data on site at Lake Thun

Module surface area and output required

As Fig. 3 shows, the winter months are critical as far as energy is concerned. As electrical energy can only be stored in batteries on the platform for short periods of time – a few days -, annual energy averages cannot be derived.

On the other hand, we may also assume that fewer trips will be made in winter, a factor which helps to reduce the problem. So to calculate the module output and surface area required, October is taken as a typical month. Hence for the three

installation variants listed above, the output and surface area figures shown in the table below are obtained:

Variant		a)	b)	c)
Module surface area	m ²	270	200	160
Installed output	kW _p	32	24	20

The values given apply for solar modules with cells made of crystalline silicon and a good degree of efficiency, as currently offered by various manufacturers.

C.7. Electrotechnical installations

The solar plant consists of the solar modules, storage batteries and the accompanying power electronics.

Solar modules

For efficiency-related reasons, only modules with crystalline silicon cells are currently feasible. The rated output of this type of module lies in the range between 120 – 140 watts per m². These modules have a long service life and are very resistant to the adverse effects of weather and the environment such as damp, snow, ice and hail.

The illustration opposite shows a section of the solar power plant at Stade de Suisse operated by BKW FMB Energy Ltd., where modules of this type are applied.



Storage batteries

Weight is not a major factor as far as application on the platform is concerned, so the use of conventional lead storage batteries is for the time being the most suitable solution (cf. section C.3.). As well as good economy, they offer a long service life, problem-free operation, good safety aspects and are easy to recycle – all important criteria. In order to ensure operation for one week, a rated capacity of 400 kWh is required – the equivalent of a battery weight of 15t.

Power electronics

Power electronics includes a) the charge regulator to ensure the optimal flow of energy from the solar modules to the batteries, b) a three-phase inverter to convert energy from the battery into alternating current suitable for grid transmission and consumer usage.

The power units on the platform draw energy straight from the batteries via their own voltage changers.

C.8. Analysis of costs

The costs for the platform in its basic version can be broken down as follows:

Project planning	180,000 CHF
Development	200,000 CHF
Permits	50,000 CHF
Steel construction (floats)	680,000 CHF
Superstructures (deck and covering)	360,000 CHF
Solar generator	510,000 CHF
Batteries	320,000 CHF
Power unit	180,000 CHF
Generator	75,000 CHF
Dynamic Positioning System	775,000 CHF
Nautical technology	70,000 CHF
Start-up	200,000 CHF
Total	<u>3,600,000 CHF</u>

As the precise version is not yet known, the above figures are cost estimates. Costs may vary, depending on the features included in the platform construction.

C.9. Solar platform team

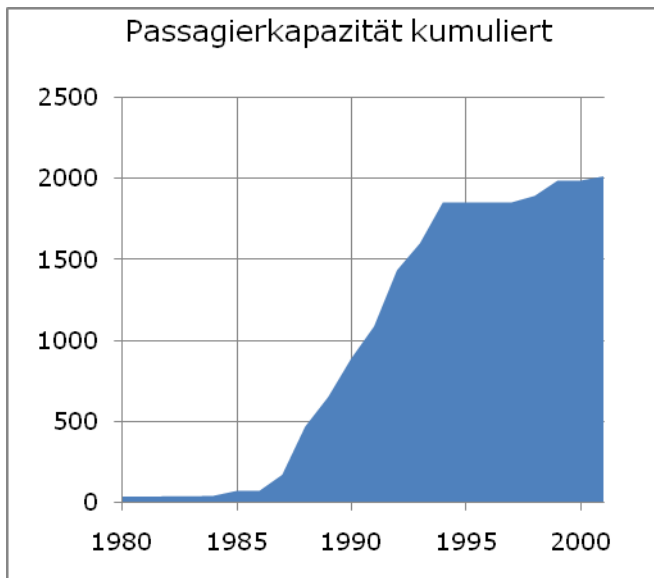
Dr. Jakob Vollenweider	BKW FMB Energy Ltd.
Mark Wüst	MV Line
Andreas Kindlimann	MV Line
Dr. Rudolf Minder	Minder Energy Consulting

D. Submarine

D.1. The application of submarines in the tourist industry

To start with, a word about definitions: a submarine is a vessel that spends more time under water than above water, i.e. is largely capable of operating autonomously. The correct term for the vessels discussed here is “submersibles” – they spend most of their time on the surface of the water and occasionally dive for a relatively short period only. As constructions of this type are commonly referred to as “submarines”, experts have no problem with this term being applied to their submersibles.

The first submarine for application in the tourist industry was the “Auguste Piccard”. 32,000 passengers dove with this vessel on Lake Geneva during EXPO 1964. The Auguste Piccard was built for 40 passengers, weighed 180 t and was capable of diving to a depth of 610 m. It is the biggest tourist submarine ever built; no other tourist submarine has been able to dive deeper.



In the mid-1970s Kawasaki Heavy Industries had plans for a 40-passenger vessel which never materialised. Since 1983 a number of companies have built tourist submarines, and from the end of the 1980s through to the mid 90s their capacity has steadily increased.

In 1961 Sulzer built the SPT-16, with room for 16 passengers. The project was discontinued after the initial dives. Experts consider it to be the best submarine ever built. The SPT-16 was stored for many years in Florida and is this year being restored by U.S Submarines Ltd. before going into operation.



Other designs are also being pursued: Baltic Submarines is developing submarines that are firmly attached via a line to a ship on the surface. The ship supplies the submarine with air and energy. These submarines are relatively inexpensive and easy to handle; however, the depths to which they can operate are somewhat limited. The question also remains as to whether the authentic “submarine feeling” isn’t somehow lost. This concept has not been pursued on the Goldfish Project.

Tourist submarines are deployed in familiar holiday and diving regions such as the Caribbean, the Red Sea, the Mediterranean, Mexico, the south Pacific islands... Of 61 planned submarines, a total of 56 have been commissioned (figures up to 2001). During this whole time there have been no accidents or notable incidents.

Location	No.	Location	No.
Grand Cayman	5	Aruba	1
Bahamas	2	Sint Maarten	1
Barbados	1	Spain	3
Rota	1	Florida	1
St.Thomas	1	Indonesia	1
St.Croix	1	France	2
Saipan	1	Monaco	1
Canary Islands	2	Taiwan	1
Hawaii	7	Malta	1
Bermuda	1	Martinique	1
South Korea	1	Mexico	1
Guam	1	Italy	2
Japan	1	Columbia	1
Okinawa	1	Fiji	1
Egypt	1	Scotland	1
Israel	1	Brazil	1
		Out of service/ Refit	7

D.2. Handling the project

A submarine is a complex product. The stringent safety regulations in particular make extensive demands of materials, design and equipment.

These constraints mean that the submarine aspect of the Goldfish Project is highly detailed yet nevertheless manageable. There is very little leeway in the design and equipment of the submarine. Many aspects are already specified, i.e. the submarine manufacturer may only compile the vessel from components which have already been cleared as being fit-for-purpose; the shape of the hull is also only allowed to vary within strict tolerances.

The sequences involved in the manufacturing process have also been predetermined. The various tests, especially tests on the pressure hull (the submarine's outer skin) need to be planned in advance so that the equipment and kit required for the testing work can be made available at the right time. Successfully passing these test stages are key milestones in the project plan. The availability of the testing kit can have a major effect on the length of time the project takes to reach completion: first, these steps need to be defined at an early stage, and second, the project plan must be strictly adhered to in order not to miss the allocated time slot.

The benefits of this type of clear planning can only be derived if the manufacturer has many years of experience in working with such regulations and is able to provide expert project management.

In other words: we need to be sure that the finished vessel will be entirely fit-for-purpose; the greatest risk comes from having access to the submarine too late or indeed not at all as the result of poor project management.

D.3. Authorisation

Authorisation can be granted by various bodies. If we decide to have our submarine built by U.S. Submarines Ltd., the American Bureau of Shipment (ABS) would issue the technical authorisation.

The ABS has a dedicated committee for tourism submarines. Bruce Jones, the managing director of U.S. Submarines, is a member of this committee and hence very well informed on the technological status currently required.

Following acceptance during the manufacturing procedure, the ABS carries out annual inspections. These inspections are supervised by an expert from ABS during the revision work, with the expert spending several days on site to this end.

D.4. Safety aspects

Adhering to the regulations should ensure worst case scenarios are excluded: a) the submarine must not leak, b) if it becomes impossible to manoeuvre the submarine, it must be brought to the surface in good time.

Below, we give detailed information on these aspects:

a) The pressure cabin with hatches and covers is tested 1:1 during manufacture. The pressure exerted during these tests lies clearly above that prevailing at the depths to which the vessel is permitted to dive. The design of the pressure cabin is such that the first signs of damage (dents) only occur when a multiple of the maximum operating pressure is reached – with the cabin leaking or even collapsing when yet much greater pressure is applied.

In concrete terms: The GOLDFISH has been designed for diving to depths of 300 m (deepest point in Lake Thun: 217 m). This vessel could sink to a depth far below 1000 m without injury or harm occurring to anyone.

b) If the submarine should sink to the bed of the lake as a result of the failure of the main power unit, five procedures are possible in order to raise the vessel to the surface without using a second submarine:

- the use of horizontal thrusters, assuming electricity is available
- blowing the control ballast tanks
- blowing the main ballast tanks
- discarding ballast elements (drop weight)
- rolling out the lifting buoy

Each of these measures is sufficient on its own to raise the submarine.

Large reserves are envisaged in order to ensure a sufficient air supply for the crew and passengers:

e.g. Type NOMAD 125h useful volume, 150h emergency volume – i.e. after a full day's operation lasting 8 hours, an air reserve sufficient for more than 10 days remains!

To prevent collisions with the bed of the lake or with other vessels, a varied selection of navigation and display systems is available. The appropriate equipment needs to be defined for application on Lake Thun.

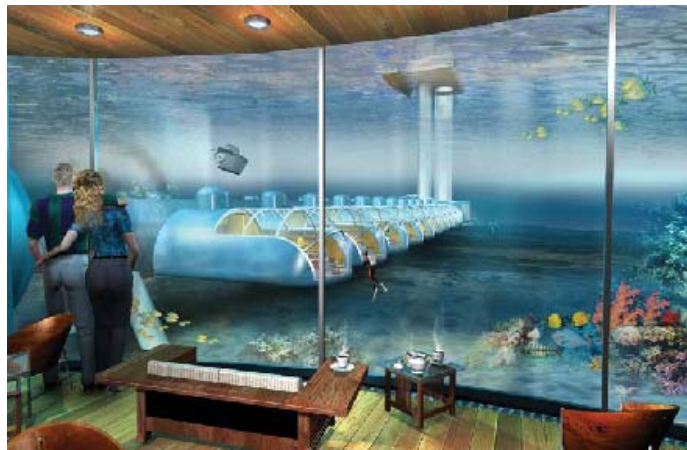


D.5. Suppliers/Partners

A number of manufacturers have been active in the tourism submarine market in recent years with varying degrees of success. Some of them build mainly experimental and research vessels. Of the four manufacturers of tourism submarines we contacted, U.S. Submarines Ltd. impressed us most of all, with its many years of broad experience. Initial queries were also dealt with in a timely and professional manner. We therefore feel we can recommend pursuing this cooperation.

USSubs was founded in 1993. Annual sales are in the order of US\$ 25 million. A core team consists of 12 employees, and for full implementation up to 40 additional employees are engaged. The production location is in Florida, the planning office in Oregon. USSubs has offices in Seattle, Dubai and Paris. This year, USSubs is building three new vessels and carrying out 1 retrofit (ex-Sulzer SPT-16).

As well as the design, engineering and construction of submarines, USSubs is also active in the development of underwater accommodation.



Our contact person is the managing director Bruce Jones. Bruce Jones is originally a geologist with a MBA degree. He has been active in the tourism submarine business for the past 20 years and is a member of the American Bureau of Shipping's Special Committee on Undersea Vehicles.

www.ussubs.com

D.6. Evaluation criteria

Supplier

Based on previous experiences a product from the wide range of products made by U.S. Submarines is a likely candidate.

Size of vessel, number of passengers

The number of passengers depends very much on the operating concept. From a technical point of view sizes of 16 or less up to 36 and more are possible. Costs do not increase in a linear progression as the number of passengers increases. Apart from the commercial aspects, the increasingly complex transport requirements and infrastructural dimensions (including excavation work) need to be taken into account.

Diameter of hull

In order to meet the requirements for a feeling of space and seating arrangements (N.B.: embarking and disembarking) the minimal, useful space cross section needs to be defined. The internal dimensions of the outer skin must be greater to allow for any insulation and infrastructure.

Hatches

Hatches for greater diving depths will be either flat and thick, or thinner and concave towards the outside. A GOLDFISH would probably be fitted with curved hatches of 60 cm diameter or even bigger.

Availability

Many things favour restricting the choice to tried and tested types of vessel. Where new developments are concerned, any uncertainties which might occur could quickly result in major delays to the project. Various used vessels are also available; this option can best be examined once the requirements made of the GOLDFISH have been sufficiently well clarified.

Diving depth

For insurance-related reasons the submarine may only be operated in those areas with depths for which it has been designed. Common vessel classes are designed for diving to depths of 100 m or 300 m. For vessels diving to greater depths, significantly more complex materials and procedures are prescribed. Lake Thun has a depth of 217 m at its deepest point, which means that a vessel design accommodating 300 m would be appropriate.

Prices

As soon as the number of passengers has been decided on, the choice will then be limited to a few types of submarines. Accordingly, a comparison will be made of their prices and of the facilities available.

Equipment

Equipment is not a major criterion as far as the choice of vessel is concerned, as virtually every submarine can be equipped with all functions needed.

D.7. Types of vessel

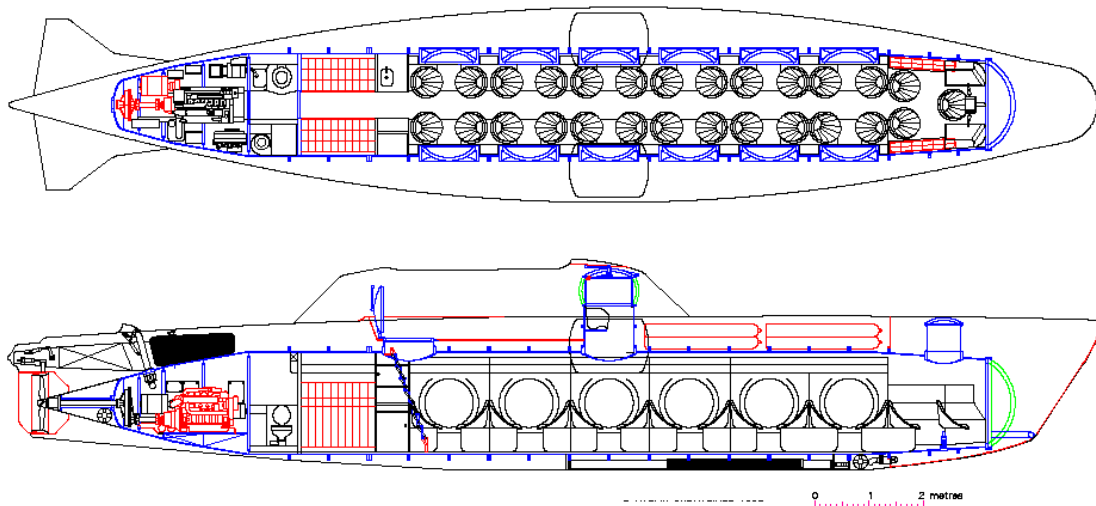
Based on the currently known requirements, two types of vessel contained in the USSubs product range can be considered:

Whereas MARLIN is designed as a lighter construction for applications accommodating approx. 16 to 24 passengers, NOMAD is intended for applications involving between 24 and 36 passengers.



		MARLIN	NOMAD
No. of passengers		16	24
Length	m	16.5	19.7
Draft	m	2.0	2.7
Weight	kg	33,000	72,000
Diving depth	m	305	305
Diameter of hatches	mm	900	600+
Diameter of pilot hatch	mm	1,485	1,524
Speed on surface of water	knots	8.0	9.0
Speed under water (horizontal)	knots	5.5	5.0

MARLIN (diagram showing plan and side elevation)



D.8. Impressionen



D.9. Submarine team

Lorenz Zellweger

Zellweger Ingenieuresellschaft mbH

Technical clarifications, data and illustration

S L. Bruce Jones

U.S. Submarines Ltd.

Aquabus C60 Cabine

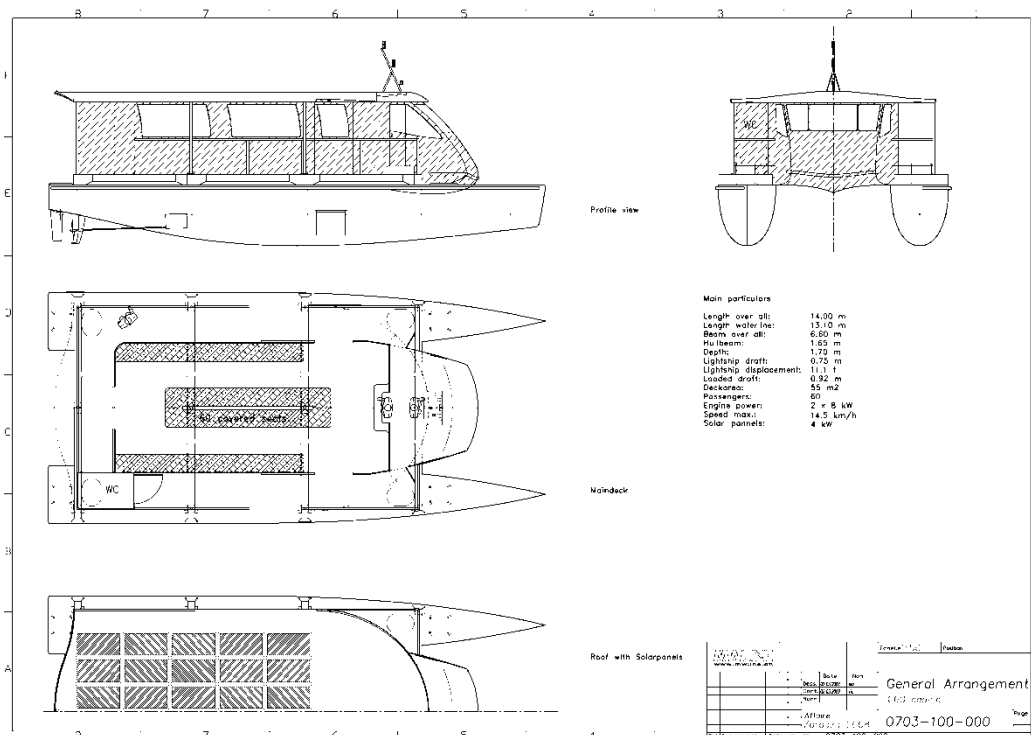
The Aquabus C60 Cabine is designed as a catamaran for public and tourist passenger transport on inland waterways. Fitted with two powerful, efficient electric motors and state-of-the-art solar panels, this solar-powered vessel is also silent and emission-free in operation.



Depending on the version, the Aquabus C60 Cabine can carry 60-80 passengers. It has been inspected as a passenger vessel by Bureau Veritas classification society and 6 units are already plying various waterways in Europe.

The SUN21, the first solar-powered ship to cross the Atlantic, is also built along the basic lines of the C60. The first 4 Aquabus C60 were commissioned by Expo'02 and as such carried 1,000,000 passengers during a period of 6 months.

- Length: 14m (special version 17m)
- Width: 6.6 m
- Height: 3.6 m
- Displacement: 14 t
- Draft: 0.95 m
- Maximum load: 85 passengers
- Hull: GFK (polyester or epoxy)
- Speed: 8 knots
- Range: 60 miles
- Authorisation: Bureau Veritas
- Price: € 647,000.-



E.2. Comparison of the two vessels

The Aquabus 1050T can carry the same number of passengers (24) as the proposed submarine and is thus suitable for shuttle operation. The ship's manageability makes operation possible with just a one-man crew on board.

With a width of 2.5 m it is relatively narrow and can easily be transported on public highways. As part of the seating is situated on the aft deck and is hence sheltered, only 16 passengers can be transported seated during bad weather.

The C60 Cabine has comfortable seating for 60 passengers. The vessel is very stable and has a large solar roof because of its large roof surface area. In view of its size, it is best if operated by a two-man crew. Under Swiss law it would, however, also be possible to operate it as a one-man vessel. The large inner space also enables the ship to be used for small banquets and group excursions.

At 6.5 m wide, it requires a large berth. Transport on public highways requires the use of a special transporter, but is possible throughout the whole of Europe.

E.3. Information on MW Line

MW Line was founded by Mark Wüst in 1991 who was later joined by Richard Mesple. Today, MW Line is a market leader in the construction of efficient, environmentally friendly ships. The shipyard and development office are located in Yvonand, at the southern end of Lake Neuenburg.

The technical team consists of marine architects and engineers and draws on a large network of technical institutes of higher education, engineering consultants, other shipbuilding engineers and nautical specialists.

It is active in a wide variety of research areas including the use of renewable energy in marine applications and integral concept solutions. MW Line has carried out the following projects among others:

- e) Hydroxy 3000 (fuel cell ship for 7 passengers) in cooperation with Heig-VD
- f) Aquabus C60-SUN21, the first ship powered by solar energy to cross the Atlantic
- g) Drafts and concept studies for the PlanetSolar trimaran - PlanetSolar is planned to be the first solar-powered ship to circumnavigate the world.

E.4. Solar-powered ferry – the team

Mark Wüst MW Line

Andreas Kindlimann MW Line

Appendix

Contact persons

Name	Function	Company	Telephone	eMail address
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Tina Limbach	Project administration for GOLDFISCH			limbi@vtxmail.ch
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Andreas Kindlimann	Platform feasibility Ferry feasibility	MW-Line SA	024 430 40 70	andreas.kindlimann@mwline.ch
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Lorenz Zellweger	Submarine feasibility	Zellweger Ingenieurgesellschaft mbH	033 223 49 11	zel@zellweger.biz

Information charts

Information overviews given on the next two pages:

- Focus on technology
- Focus on confidence