THE CHALLENGES OF BLAST FURNACE REBUILD[1]

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Abstract
SVAI has in total rebuilt more than 300 Blast Furnaces. Some references for recent years are Mittal Vanderbijlpark D BF, VA Stahl A, Mittal Indiana Harbour No7 and CSN No3. The key strengths of the company are international experience, capability for contract management and supply of all kind of equipment to suit client standard and adaptation of each client's requirements. The modern rebuild techniques that include modular type can be used including planning. This paper will talk about the rebuilds done by SVAI in the Brazilian market that include CSN, Acesita, Usiminas and COSIPA Blast Furnaces. Acesita and CSN rebuilt their furnace in 2001. The CSN project involved the increase of the capacity from 8,000 tonnes per day to an average of 9,400 tonnes per day. It was considered a modular type rebuild for CSN and Acesita project. USIMINAS BF No2 with 7 m hearth was rebuilt in 2003. SVAI has supplied mechanical equipment, erection and commissioning supervision. COSIPA BF 1 has been rebuilt this year. SVAI supplied mechanical equipment within one year programme. Time for these rebuilds has always been a challenge. This paper will show how SVAI worked and found the solutions for timing problems. CSN was rebuilt within 98 days and Acesita within 60 days. For USIMINAS and COSIPA BF the erection was not SVAI responsibility but the engineering and supply was within one year. A good planning and experience on rebuild and on the local conditions make the difference for the success of the entire job.
Key words: Blast furnace; Rebuild; SVAI; Brazil

OS DESAFIOS DAS REFORMAS DE ALTOS-FORNOS

Resumo
A SVAI já realizou reformas em mais de 300 altos-fornos. Como referências de trabalhos recentes citam-se os altos-fornos: B da Mittal Vanderbjilpark, A da VA Stahl, n°. 7 da Mittal Indiana Harbour e n°. 3 da CSN. Os pontos fortes da companhia são experiência internacional, capacitação para o gerenciamento de contratos e fornecimento de todo tipo de equipamento para se adequar aos padrões dos clientes, e adaptação às suas necessidades. Modernas técnicas de reforma, incluindo a reforma em grandes blocos, podem ser empregadas com um planejamento de boa qualidade planejamento. Este trabalho trata de reformas realizadas pela SVAI no mercado brasileiro, incluindo altos-fornos da CSN, Acesita, Usiminas e COSIPA. Acesita e CSN reformaram seus fornos em 2001. O Projeto da CSN envolveu o aumento da capacidade de 8000 toneladas diárias para uma média de 9000 toneladas por dia. Considerou-se a reforma em módulos (grandes blocos) para os projetos da CSN e da Acesita. A reforma do alto-forno n°. 2 da Usiminas, cujo diâmetro do cadinho é de 7 m, ocorreu em 2003. A SVAI forneceu o equipamento mecânico, supervisão de montagem e de comissionamento. O alto-forno 1 da COSIPA foi reformado este ano. O equipamento mecânico foi fornecido pela SVAI em um período de um ano. O tempo sempre foi um desafio na realização dessas reformas. Este trabalho apresenta os meios encontrados pela SVAI para solucionar problemas relacionados ao tempo. Os fornos da CSN e da Acesita foram reformados em 98 e 60 dias, respectivamente. A SVAI não foi responsável pela montagem dos fornos de Usiminas e COSIPA, mas forneceu o equipamento mecânico em um ano. Planejamento bem executado e experiência com reformas e conhecimento do mercado local fazem a diferença para o sucesso de todo o trabalho.
Palavras-chave: Alto-forno; Reforma; SVAI; Brasil.

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1 CSN N^{O} 3 Blast Furnace Rebuild

The CSN No. 3 blast furnace was rebuilt and modernised in 2001. When the CSN rebuild project started it was set two fundamental project goals. Firstly, it was required that the reline would be completed in the shortest possible time. The initial target for the rebuild was a 93 day outage period, although this was subsequently increased due to problems encountered at site. The second goal was that the project would achieve high safety standards. In essence, a zero tolerance to accidents was set.

The project was essentially a turnkey one and was carried out by a consortium which comprised of a number of SVAI companies (SVAI UK / SVAI Linz / SVAI BR) and Setal Engenharia and Construções. SVAI UK was responsible for the general project management, basic engineering, some detail engineering, imported supply, start-up and operational assistance. Setal did most of the detailing engineering, local supply, civil works and construction together with SVAI BR. SVAI Linz provided the control system and CORUS provided operational assistance. CSN were also involved in many areas of the project and their encouragement proved to be invaluable during the various phases of the project.

The contract was placed on the 9th August 1999 and the furnace was blown in on 7th August 2001, giving a program of 24 months. The key activities and dates within this program were as follows:

Engineering and Procurement of equipment:	Month 1 to 19
Site set up:	Month 9
Receipt of first deliveries at off-site office:	Month 9 to 20
Pre-shutdown work:	Month 15 to 21
Furnace blow out 1 March 2001:	Month 21
Furnace Rebuild period:	Month 21 to 24

The overall program was tight; however the consortium agreement gave an advantage in that a large part of the equipment supply came from Brazil. This arrangement was crucial to the project success.

The original furnace design included a two bell type of charging system and plates for cooling of the shell. The furnace was originally designed for a production in the order of 8700 t/day. The new furnace differed from the old one in the following areas:

- Hearth Diameter was increased from 13.0 m to 13.5 m.
- Inner volume was increased by approx. 11% (3815 to 4247m3)
- Daily production was increased from 8700 t/day to an average of 9400 t/day with a maximum of 11000 t/day.
- Number of tuyeres was increased to 38 from 34.
- Copper and cast iron staves were used for furnace cooling. Copper staves being incorporated in the high heat flux zones around the bosh and belly.
- A twin or parallel hopper bell less top replaced the original twin bell top.
- The gas cleaning plant was replaced with an annular gap scrubber with external demister. The design provided allows for the future installation of a top gas recovery turbine.

Previous experience from other SVAI UK projects was applied to make the CSN rebuild a success. The rebuild carried out by SVAI UK at CORUS Port Talbot was particularly important in this regard. The amount of pre shut down assembly work assisted in the overall success of the project. This means that items were made available for immediate installation when they were needed. At the height of the rebuild about 1800 personnel were present on day shifts and about 800 on night shifts. The construction procedure was in simple terms a reverse of the demolition procedure. The lower areas of the furnace were constructed from the bottom up with the hearth, bosh, belly and some of the lower stack being placed first, then the top cone was lifted into position and placed onto the jacks. Then the upper stack was positioned underneath the top cone and the rest of the furnace was constructed from the top down. The project benefited from the large amount of pre-shutdown work was:

- The furnace shell rings (8 off) being constructed and trial fitted;
- The cast iron and copper staves were also trial fitted to minimise erection time during the rebuild phase;
- The furnace top structure was built and the majority of the bell less top equipment constructed pre outage;
- The stave stitch pipe work and hydraulic system pipe work were pre-fabricated;

It is shown in Figure 1 the pre-assembly area used prior to the outage period.

Figure 1. Pre-assembly area.

The bustle main can be seen in the foreground with the furnace rings in the background. The pre-assembly area was positioned within an active area of ironmaking at the CSN site and this therefore gives limitations for the possibilities of pre-assembly. The scale of the main crane that was utilised for all the major lifts is shown in Figure 2. It had a capacity of 240 tonnes at a radius of 24 m. The existing outrigger crane on the furnace was also used for the positioning of the modules. The crane was specifically supplied for the purposes of the outage from Europe.

Figure 2. Crane with 240 tonnes capacity.

It can be seen in Figure 3 how the staves were delivered into the furnace and how they were installed.

Figure 3. Installation methods for staves.

The existing cast floor was re-used with new iron and slag troughs. Four new SVAI guns and drills were supplied with two hydraulic systems housed in existing rooms. A new metallic tuyere platform was installed. The existing fume extraction system was modified for higher efficiency and to achieve a cleaner casthouse environment.

The furnace blow-down was very critical for the project because, if a large salamander were to be left inside the furnace, the planned outage time would be increased due to the extended demolition time. One week before the shutdown the furnace came off blast for 24 hours to enable both furnace and salamander mechanical preparation work. This was followed by four days of furnace stabilizing operation. The furnace was blown down over a 16 hour period with the salamander tap taking place in the last 4 hours of burden blowdown. The salamander was tapped from two points into flat bed trucks. Torpedoes were not used because of the low position of the existing salamander tap holes. About 1300 t of salamander was removed leaving an estimated 120 t inside the furnace. After the salamander tap, the burden quench pipework was prepared. The burden was then quenched for a 24-hour period. The effluent water passed via the slag granulation plant to the effluent treatment plant and was eventually released into a local water system after considerable treatment. The water quality for discharge was strictly controlled.

For the blow-in, the furnace leak test and dry out was performed as one action over a two and a half day period. A leak test up to 1.0 bar g was performed using the main blower with cold blast providing wind at 2000 Nm^3/minute with the gas cleaning plant utilised to create the back pressure. The wind passed to atmosphere through the gas cleaning plant cone change manhole. The furnace was leak tested 3 times in order to identify leaks. When the furnace leak test was complete, the wind temperature was stepwise increased to give a final hold temperature of 450^{o}C for one and a half days. After the furnace leak test and dry out a 2 m bed of coke was put into the hearth. It was decided to timber the furnace instead of using an all coke hearth fill. The 130 tonnes of timber were dropped into the furnace on pallets through the bell less top chute change door. This action saved about 2 days on the overall programme. The furnace proper was filled in automatic via the furnace top, with a final ore to coke ratio of 2.2 achieved in the throat area. During the furnace fill the bell less top burden trajectory profiles were measured using an impact probe technique. This took approximately 24 hours.

Blowdown took place on the 1st of May 2001 with the blow-in taking place on the 7th August. Additional work executed during the outage for repairs to the baseplate covered a period of 2.5 days. Delays during the outage covered a further period of 3 days. Thus the revised target project program became 98.5 days. The actual outage duration was within this period i.e. 98 days. In other words, the furnace blew in ahead of the revised date. One of the main goals of the project was to have zero accidents. This was achieved due to the care and diligence of all parties, and was a major achievement for all concerned.

The furnace reached its average daily production design figure after 15 days. This was particularly due to the professional manner in which CSN conducted this phase of the project. It is possible to see in Figure 4, the actual daily production against the Corus plan and CSN Plan.

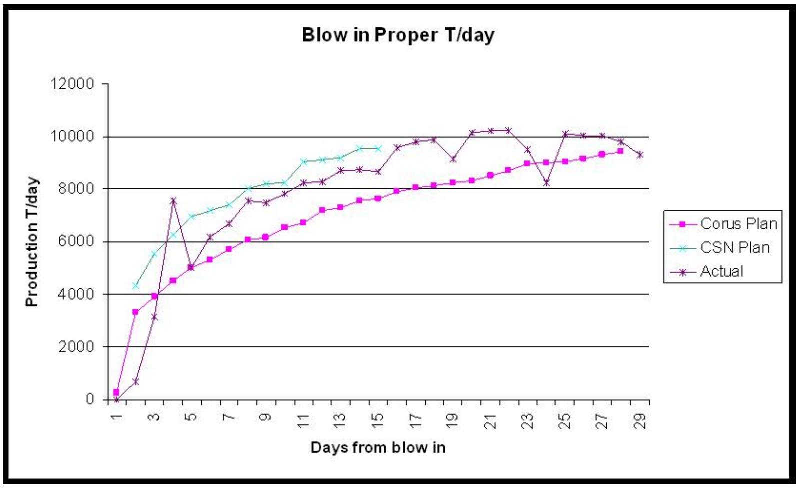

Figure 4. Production Rump Up.

2 ACESITA N^O 2 BLAST FURNACE REBUILD

The Acesita (actual ArcelorMittal Inox) No. 2 blast furnace was rebuilt and modernised in 2001 with the modular configuration as CSN. A new average production level of 1270 tonnes/day of hot metal was required and 53 day of shut-down period. Previous experience from other SVAI UK projects was applied to make the Acesita rebuild a success. The restrictive site layout and design of tower limited the module size. Again, the amount of pre shut down assembly work assisted in the overall success of the project. The maximum lift used was 100 tonnes using of a heavy lift crane (skyhorse).

3 USIMINAS N^{O} 2 BLAST FURNACE REBUILD

The third revamp of the USIMINAS No 2 blast furnace was in 2003. The contract was signed on 7th October 2002. The project had the following aims:

- Start of contract on 7th October 2002 and Shut Down on 13th September 2003;
- Last deliveries 11 months after contract signature;
- 85 days shut down period.

The project was essentially engineering and supply of mechanical equipment for the third revamp of USIMINAS Blast Furnace 2. SVAI BR was the main contractor supported by SVAI UK. SVAI UK was the responsible technological centre and they were responsible basically to approve the flowsheets and functional description prepared in Brazil by SVAI BR. USIMINAS split the package and some of the other main contractors were Reframax, for the refractory supply and installation, Alstom (actual Converteam) for the Electrical, Instrumentation and Automation design, supply and installation; USIMINAS Mecânica responsible for the erection.

The scope of SVAI BR included design, manufacturing, supply, transportation, inspection, tests and management of the project for the Mechanical equipment for BF No 2. It also included a new slag granulation system for Blast Furnace 1 and civil basic and detail engineering. The main Blast Furnace operational data did not change after the rebuild.

Annual Production	785.000 ton
Daily Production	2.150 ton/day
Blast Air Volume	72.000 Nm3/h
Blast Pressure	1,2 kg_f/cm^2 g
PCI (maximum)	150 kg/ton
Main Dimensions	
Hearth	7m
Internal Volume	885 m^3

The main items supplied by SVAI were as follows:

- Complete cooling system, including piping and accessories, pumps, troughs, tanks for both for the high pressure and low pressure system;
- BF /Stoves platforms;
- Utilities system (compressed air, lubrication system, nitrogen, COG, industrial water, potable water);
- Valves Repairs (Google valve, gas valve, etc);
- Gas ducts replacement;
- Bleeder valves supply;
- Hoist, Monorail for most of maintenance areas (stoves, BF top, tuyere stock, etc.);
- Expansion Joints for gas ducts;
- Stockhouse equipments supply (screens, wearing plates, chutes, vibrating feeders, conveyors revamp and increase capacity);
- Revamp of skip car;

- Slag granulation new system;
- Dedusting ducts and dust handling (pneumatic transport);
- Casthouse crane revamp with changes in design;
- Slag granulation crane revamp;
- Temporary equipments for erection, bow-down and blow-in.

SVAI reviewed the process conditions for the BF cooling system, including the functional description and commissioning supervision. The slag granulation basic and detail design, functional description and commissioning supervision were also part of the scope. It was mandatory to follow USIMINAS standards in each phase of project. In Figure 5 it is possible to see the new slag granulation in operation and the new pipes for the furnace cooling circuit.

Figure 5: New slag granulation in operation and new pipes for the BF cooling system.

COBRAPI was SVAI's supplier that developed the basic and detail design of the project with SVAI supervision. Basic design was carried out by SVAI/COBRAPI. SVAI completed all the process design for the cooling system, slag granulation and de-dusting. Effectively, SVAI UK was responsible for process know how and verification of the key project documents. Planning of all activities was done within the SVAI BR team. Specialists in purchasing, quality control, inspection, logistics from the complete scope of the project were involved in all the phases of the contract to execute the project according to schedule. Each month a progress report was prepared of the activities with the overview of the project management, engineering progress, purchase orders and deliveries, monthly actualization, commercial situation etc. USIMINAS worked together with SVAI as a team approving drawings and together defining their necessities and interfaces between the other packages. During the erection phase (not part of SVAI scope of supply), a SVAI team was required to help USIMINAS with interfaces of SVAI supply and possible problems. The programmed main activities according to the contract were:

Contracted Signature	07th October, 2002
Basic Project Revision	Month 3
First Items delivery	month 7
Detailed Engineering	month 7
Last Deliveries	month 11
Start of the revamp	month 12
Blow-down (85 days)	month 12 to 14
Blow-in	month 15
As built	month 16

The big challenge was the activity “first deliveries”. This included most of small pipe spools (less than 4”), lubrication system and part of the temporary equipments. In order to reach the first delivery date (31.03.03) SVAI prioritized engineering support to the technical specification, procurement activities and purchase process. It was necessary to use advanced bill of materials to avoid delays. Also to avoid delays, considering the short delivery time, SVAI increased the inspection and expediting team. All these actions made it possible to obtain no relevant delays, with no impact on the erection works under USIMINAS responsibility. The engineering was the main critical phase and due to some delays, it was necessary to manage the procurement phase with no timing gaps. Additional resources were required in order to check drawings. Another difficulty was to indentify together with the client the interfaces between the other packages and the take over points.

The main action to increase project performance was the identification of long delivery items: it was considered critical that any item with a delivery of longer than six months was highlighted during the initial phase of the project. Another action was to contract additional resources to check engineering drawings and, in this way, avoid mistakes and possible re-fabrication works during erection. The integration between departments allowed SVAI to reach the main project target. Periodical meetings with SVAI directors and SVAI UK were held to inform about project status and to involve necessary high level team members in the solution of envisaged problems. The interface with the customer was done basically through weekly meetings, where all technical, commercial and contractual subjects were discussed.

4 COSIPA NO 1 BLAST FURNACE REBUILD

The fifth revamp of COSIPA No. 1 blast furnace was in 2008. The contract was signed on 28th November 2006. The project had the following aims:

- Start of contract on 11th December 2006 and Shut Down on 7th January 2008;
- Last deliveries 12 months after contract signature;
- 70 days shut down period.

The project was essentially engineering and supply of mechanical equipment for the fifth revamp of COSIPA Blast Furnace 1. SVAI BR was the main contractor supported by SVAI UK. This contract, differencing from USIMINAS’ contract, did not include a process review. USIMINAS completed the process design for casthouse dedusting, furnace cooling system and slag granulation by themselves. USIMINAS split the package and some of the others main contractors were: Calorisol, for the refractory supply and installation on the furnace; Converteam for electrical, instrumentation and automation design, supply and installation; USIMINAS Mecânica for the erection and integration of the civil works. The scope of SVAI BR included design, manufacturing, supply, transportation, inspection, tests and management of the project for the mechanical equipments for BF No1. The basic and detailed civil engineering for the stockhouse area was part of the scope of supply. The main Blast Furnace operational data did not change after the rebuild.

Annual Production	1.200.000 ton
Daily Production	3.200 ton/day
Blast Air Volume	190.000 Nm^3/h
Blast Pressure	2,5 kg_f/cm^2 g
PCI (maximum)	150 kg/ton

Main Dimensions

Hearth	9,8 m
Internal Volume	1.829 m^3

The main items supplied by SVAI were as follows:

- Parts of Shell (Hearth, Rings in the Stack area);
- Complete cooling system including piping and accessories, underhearth piping, plates for the complete shell;
- Plates of throat armour, fixed temperature probe;
- Casthouse crane and outrigger crane revamp;
- Large bell supply and parts of the small bell;
- Valve revamp e.g. seal valve, seal valve, bleeder valves and goggle valve;
- Rotary chute revamp;
- Several platform steel structure substitution;
- Equalising and relief piping and top utilities piping;
- Revamp of mud gun;
- Slag granulation equipments supply (pipes, cooling tower, chimney);
- Modification of the exiting charging system (stockhouse);
- Skip area revamp (gearbox, rails)
- Revamp of hydraulic unit for top pressure control and stoves;

The main sub-suppliers from SVAI for this contract were: COBRAPI developed the detail design of the project with SVAI supervision; UMSA supplied the shell and the assembly of the large bell; USIMINAS Foundry in Ipatinga cast the large bell itself contracted by SVAI; Küttner do Brasil designed and supplied the modification on the stockhouse including civil works; Cecal fabricated the cooler plates, tuyeres and tuyere coolers; Movitec made the revamp of all cranes; Marfin engineered and fabricated the major steel structure of the project; YUTEC revamped and supplied the hydraulics. SVAI coordinated, technically supported and integrated all the sub-suppliers in order to complete the scope of supply.

Planning of all activities was done within SVAI BR team. Specialists in purchasing, quality control, inspection, logistics for the complete scope of the project were involved in all phases of the contract to execute the project according to schedule. Each month a progress report was prepared of the activities with the overview of the project manager covering engineering progress, purchase orders and deliveries, monthly actualization and the commercial situation. USIMINAS/COSIPA worked together with SVAI as a team approving drawings and together defining their necessities and interfaces between the other packages. During the erection phase (not part of SVAI scope of supply) a SVAI team was involved to help USIMINAS with the interfaces of SVAI supply and potential problems. The programmed main activities according to the contract were:

Start of Contract	11th December, 2006
Hearth Shell delivery	15/09/2007
Stack Shell delivery	07/12/2007
Crane 89 Revamp	finished by 26/09/2007
Last Deliveries	31/12/2007
Blow-down (70 days)	07/01/2008
Blow-in	16/03/2008
As built	14/06/2008

The main results of the activities and learning problems of the project are described below. The cranes were delivered without major problems. The revamp of the cranes was scheduled and re-scheduled many times due to operational requirements of the blast furnace. Good experience with the position change of the electrical panels from the crane to an electrical room. Slag Granulation Chimney was supplied by Polyplaster without major problem, some delays during engineering phase was eliminated during fabrication phase. The solution of the pin to allow the chimney movement was executed during fabrication phase with good performance. In the Figure 6 it is possible to see the new chimney after erection.

Figure 6: BF1 overview with new slag granulation chimney.

Since COSIPA is a plant near the sea, all the steel structures were supplied with atmospheric corrosion resistant material (e.g. USI SAC 300/350 or COS-AR-COR 400). All the cooling plates were supplied shop tested for pressure and leakage. A good fabrication performance was noted in general. For the hydraulic unit, some difficulties occurred during commissioning with some performance problems. The main reason was that the scope covered the revamp of the main unit only, but not of the entire system. Some existing parts could work against the good performance of the system. This is a very good example of an interface problem with a difficult solution. The mud Gun and the rotary chute were also shop tested. This shop test was essential for the good performance of the equipment on site. The company HT erected and shop tested the mud gun. For the rotary chute, UMSA erected, shop tested and balanced the equipment. A post definition of the complete scope of valves, joints, cranes revamp was necessary, since the pre-definition with the equipment in operation is very poor. The final scope of the revamp was defined together with the client for final commercial negotiations. A good relationship between SVAI and the Client allowed the correct decision to be made for the best performance of the equipment. Some problems occurred during casting of the large bell. The efficient machining and repair at UMSA made possible a good final product and within the timing of the Client's necessities. Due to old documentation without "as built" SVAI used 3D design program to check and avoid undesirable interferences. 3D design and 3D scanning system was used to guarantee a perfect coupling between the large bell and its wear plates. Also it was also used to ensure the large bell thickness.

One good experience from the project was to put inside the detailing engineer company a SVAI representative. This person made easier and faster the solution of the problems. It was also important during the beginning of the project, a person inside the Client's team to provide, again, fast answers. No major problems occurred during design. Good experience resulted with the design company inside the Client's team during erection, in order to easily correct drawings.

Results of Main Activities	
Hearth Shell deliver	18/09/2007
Stack Shell delivery	15/11/2007
Crane 89 Revamp	finished by 15/02/2008
Last Deliveries	31/12/2007
Blow-down	16/02/2008

USIMINAS proposed a new shut down period agreed together with the regional union with 85 days from 16/02/2008 to 10/05/2008. The real Blow-in day was on 04/06/2008. New problems during the revamp made the necessity for a new schedule for blow-in. One of the main problems was that the stoves suffered some chequers broken during the shut down period. It was necessary to fabricate and install new chequers in a very short period of time. USIMINAS together with the nominated refractory company did a good job to achieve this new time.

The main action to increase project performance was, in the beginning, the identification of long delivery items: priority items were considered to be the shell, big bell, stockhouse and cranes. These items were the first priority for purchase orders.

5 CONCLUSION

All 4 Blast Furnaces revamp projects reached the main target on time, within scope and to the required quality. Some delay was not critical, and in reality this always happens. The rotary joint from the mud gun, for example, in COSIPA BF1 project, had to be imported with a long delivery time. SVAI worked together as a team with USIMINAS to solve this problem with the use of the spare that was available at COSIPA site. The new rotary joint supplied will therefore replace the used spare.

SVAI flexibility was the fundamental characteristic to recover lost time in all projects. This was possible due to the high integration level and efficient communication during the critical project phases. SVAI UK was important for both turnkey projects (CSN/Acesita) and engineering and supply projects (USIMINAS/COSIPA). Previous experience from other SVAI UK projects was applied to make the rebuild a success. The projects with modular type and big amount of pre shut down assembly work assisted in the limited shut down period. For USIMINAS and COSIPA projects, SVAI UK helped as an advisor and technological center. This was important to have a support from an experienced company available in case of necessity.

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