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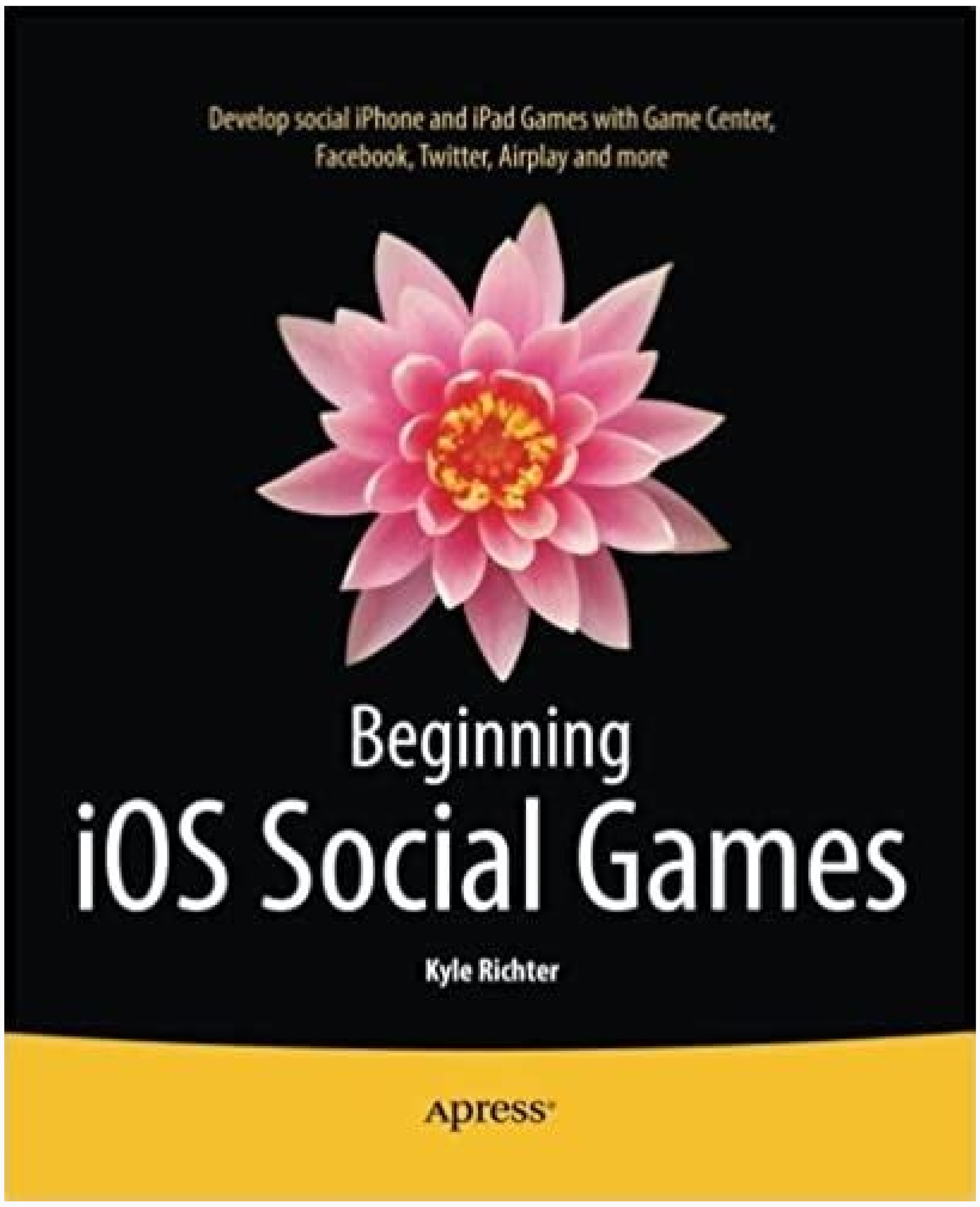
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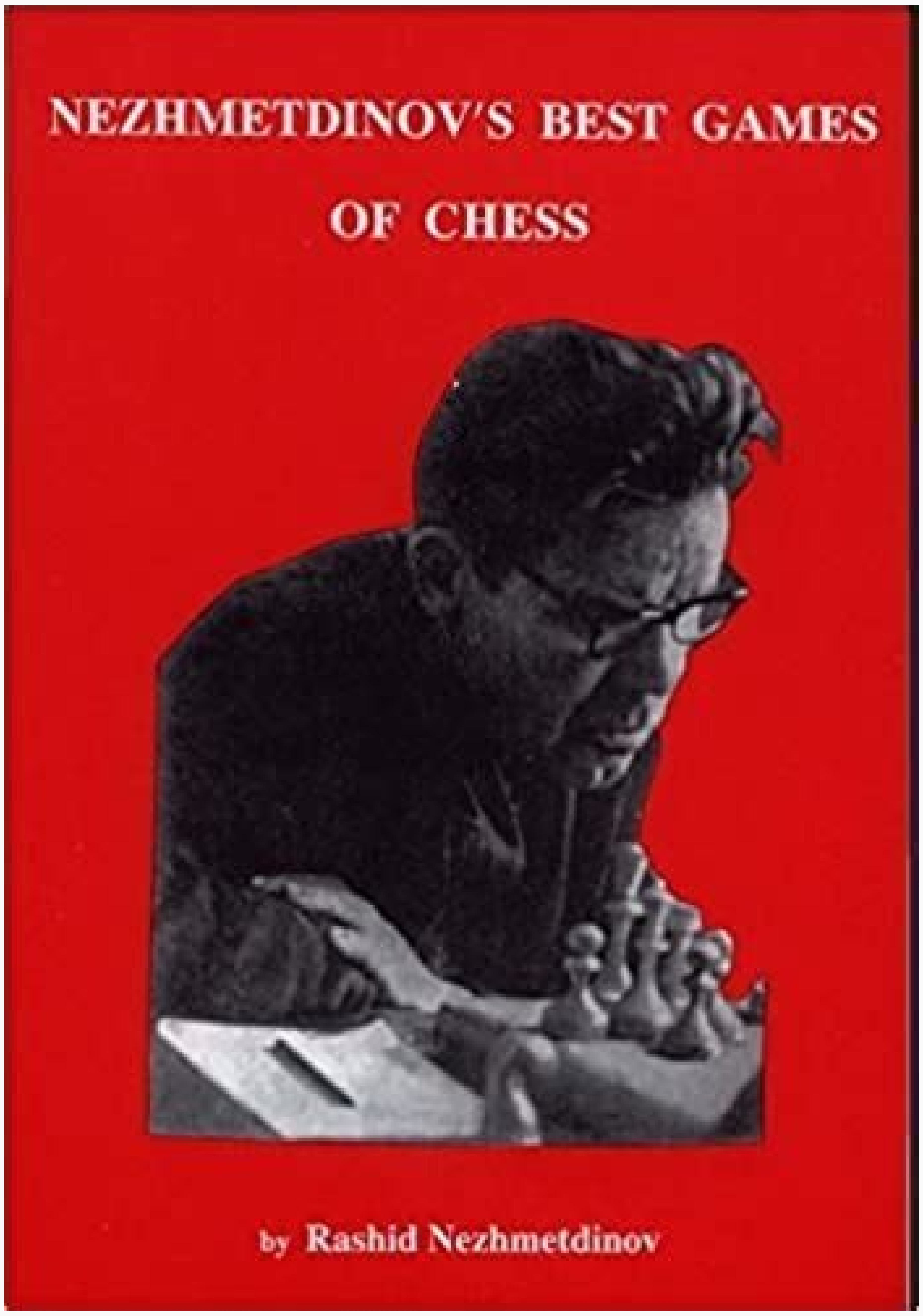
NEZHMETDINOV'S BEST GAMES
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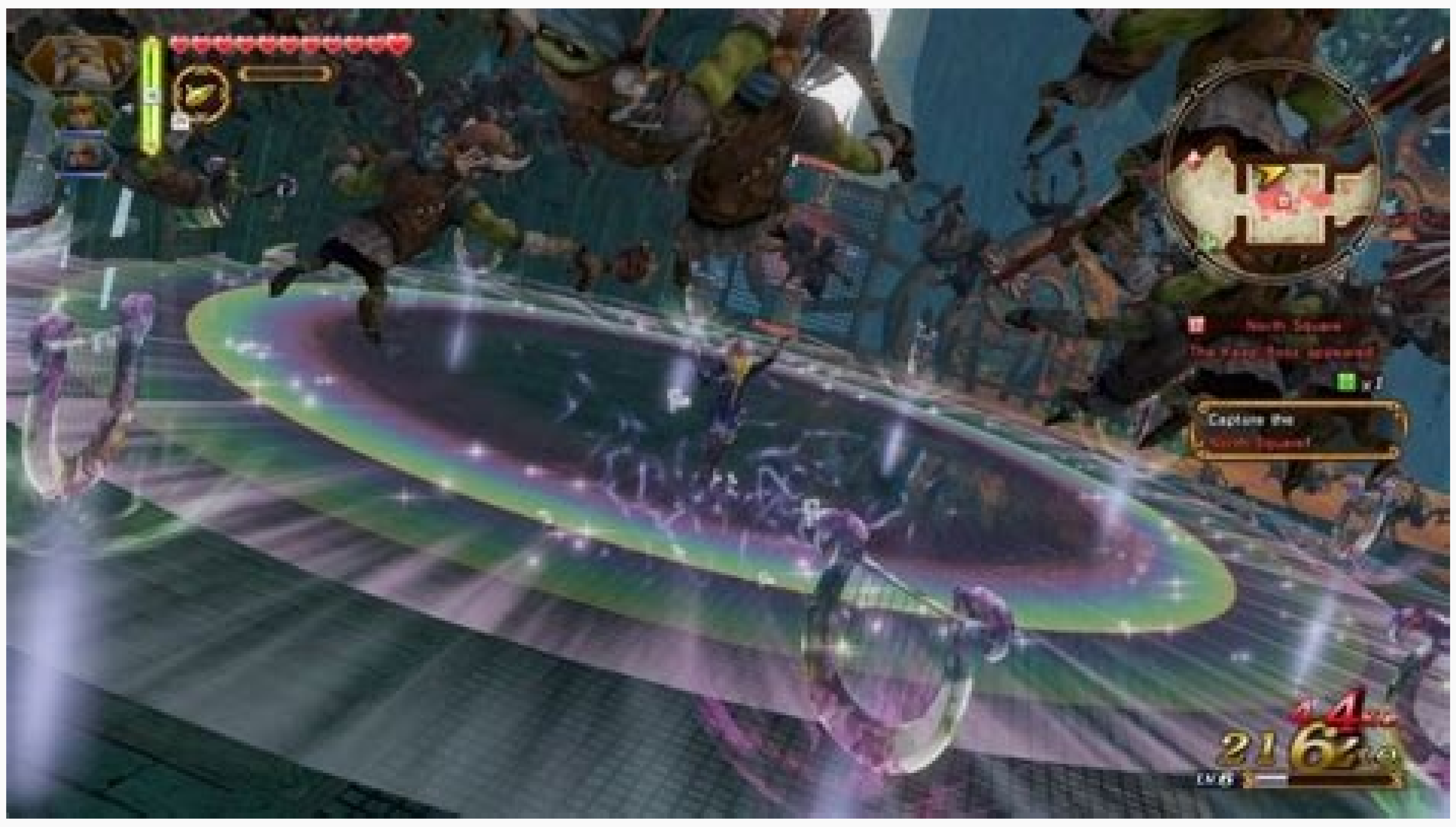

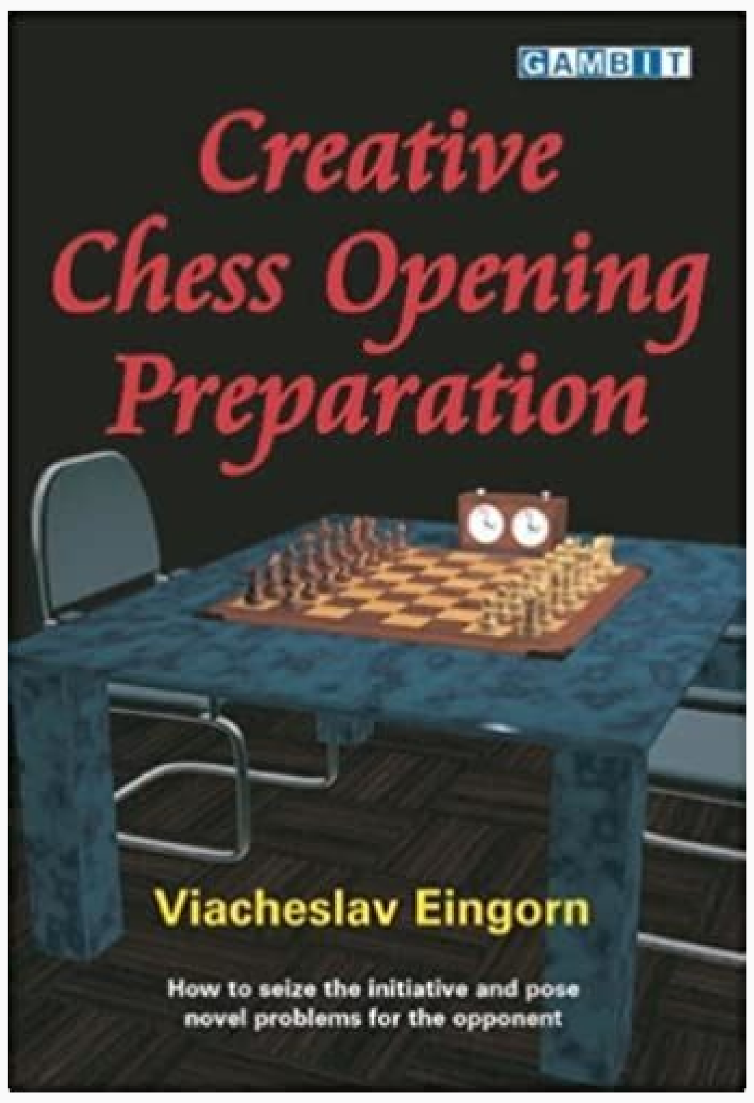

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The National Airman and Space (NASA) X-15 is a Hyper-Shop of Rocket that managed to reach Mach 6.72 with its first flight in June 1959. A variant more Recent, the X-43A increased this limit to Mach 9.65 with the realization of the use of a SCRAMJET engine of AMA Respiration [1]. With travel travels at Mach © Dia flight speeds between Mach 0.82 and 0.86, transatclosed flights such as New York and London can take more than seven hours. Although Concorde has temporarily reduced this flight time to 3.5 h, its luxury remains only one memory due to its retirement in 2003 - a result of increased combustible and maintenance costs. The purpose of the hypersan flight is an attractive thinking for most of the population, including those with business needs, personal travel and emergency situations, such as Mother Evacuation. The challenges faced by the Commercial Hypersomic Flight consist of vain aspects that vary from the form of healthy bars (which are prohibited by most terrestrial masses), in addition to dealing with the most aspects tinnic, such as the so -called superfanic management and wet propulsion systems. From the vain From the X-43A, it was established that the superphyte temperatures rapidly increased to 950 ° C [2], let alone the Trical Tormica for such a hypersonic vehicle which reach 1370 Â°ÂC at Mach 12 flight¢ÂÂwell beyond the thermal limitations of most commonly used aerospace materials. Since a hypersonic aircraft operates at subsonic ($M < 1$), supersonic ($1 < M < 5$) and hypersonic ($M > 5$) flight conditions, its drag characteristics will vary drastically throughout the different regimes. Subsonic flight experiences a significant component of drag from lift induced drag, whereas supersonic and hypersonic flight experiences mainly base and wave drag [3]. Base drag is the partial vacuum formed aft of the aircraft as the vehicle passes through the air, and wave drag is a result of the formation of shock waves. Base and wave drag are directly influenced by the volume and cross-sectional area of the vehicle, so it is imperative that these are kept to a minimum [4]. With regards to commercial hypersonic flight, there will need to be a compromise made between payload and aerodynamic design which will determine the operational efficiency and feasibility for an airline [5]. The aircraft design will need to take into consideration the method of lift generation when flying at hypersonic speeds; more specifically, some designs utilise the aerodynamic forces generated on the aircraft underbody to assist in providing lift at high altitudes where the air density is significantly lower than at sea level. The SR-71 was an aircraft using this technique to assist in lift generation, flying with a +3Â°Â attitude at supersonic speed to help increase the coefficient of lift (CL), reducing the need for increased wing size in an effort to maintain an aerodynamic profile.To achieve hypersonic velocity, combined-cycled engines of varying configurations have been proposed over the years and this paper proposes once such cycle focussing on the intermediate (ramjet) stage to propel the concept aircraft proposed up to Mach 5 before the hypersonic (scramjet) stage kicks-in.The ramjet , and ; hin d'aht t'st esnemmi dna sevaw kcohs fo noitamrof eht ot eud 2.2 hcaM naht retaerg sdeep ta egamad larutcurts elbaredisnoc ecneirepxe dluow hcihw tejobrut lacipyt a foht naht retaergSystem. A ramjet-scramjet combination is doubled in Figure 1, so that during the high altitude SCRAMJET, Ramjet entrances are sealed to prevent induced excessive drag from preventing Ramjet entrances. by shock waves in Ramjet's body. The requirement of this aircraft went to the Mach 8 cruise flight supported for a substantial part of the vain envelope, with the ramjets assisting during phases 2 and 3 of the vain envelope (Table 1). The conceptual aircraft, as well as its fuel characteristics, were detailed in previous publications [6,7,8]. The first aspect to consider is the fan input, which will need to provide the necessary air mass to the engine on the engine in all operational conditions. The required air mass is determined by the amount of impulse necessary to boost the vehicle of the region where turbocharges lose the effectiveness (Mach 2.5), to the starting point of the scramjet envelope (Circa Mach 4.5). The number of Mach, altitude and attitude of the aircraft influencing the design and performance of the RAMJET and should be taken into consideration. The following schemes show the results numerical of the use of different input configurations (ie, it is a ramp configurations) in different Mach. These boards are used to ensure that subsequent CFD results (Ansys Fluenta using ANSYS WORKBENCH 17) get similar results regarding the number of Mach and Flow Properties in Different waves of oblocal and normal shock. In addition to the validation reached through the number of dwarf, it was decided to use a verified configuration of RAMJET input CFD presented by the school of Naval Public CALIFENCY. This comparison also confirmed the reliability of the results and ensured that the mesh and the appropriate contour conditions were used. The test conditions were defined in 4 With static pressure at the entrance of 7378 PA. A comparison of the verified results of the CFD is shown in in 2b [9], which can be seen as satisfactorily resembles the results of the CFD obtained in this article (Figure 2a). The flow and geometry conditions were idy and the results (comparing profiles and speed values) were within a range of 5%, which was considered acceptable. A slight variation in the location of the terminal shock in the results reached in this report. Here, the normal shock was pushed a little for the transactions as a result of the difference in the mesh density. However, as the results are very similar, it can be inferred that the configuration of the CFD used in this report is representative for the current flight conditions and produce results. For tapes operating in the high mimers Mach, it is desirable to keep a straight place. Alternative projects include slightly curved bonnets to help manipulate the direction of air flow; However, as the Mach Mach increases, the curved hooded lady reduces the efficiency of the entrance. For confidential results, the CFD Â ours, it is crucial that the correct contour conditions, models and solutions are being used to be used in the appropriate conditions. With RAMJET operating under Super Surface Conditions, it is crucial that this is reflected with precision in the configuration of the problem. The contour conditions were defined as follows: the RAMJET structure was defined as "Wall", allowing the condition without sliding, and the domain of the surrounding fluid was defined as "distant pressure" to activate " The entry of the surrounding stretch pressure, temperature, turmoil and no member MACH [10]. The type of solution chosen was "based on density" due to the high member Mach and compressible nature of the flow; The motors of number of number were defined as "implaces" and "second order" due to the need for coupled equations (pressure and density). The simulation was performed under conditions uotluser uotluser ossI .opmet od apate rop seµÃ§Ãareti 02 moc ,opmet ed sapate 005 arap ,s 10,0 ed opmet ed apate amu moc a a total simulation time of 5 s, allowing for convergence of the simulation and stabilisation of the flow. Further details of the mesh and the sensitivity study conducted are provided in Appendix A.1.Figure 3 shows two configurations for the ramjet inlet; in Configuration A, the shock has been pushed back into the diverging section of the inlet. This allows for stability of the shock but does not produce efficient pressure recovery. For optimum pressure recovery (pressure rise in the intake due to flow deceleration), the shock should be nearer the inlet throat as in Configuration B. The spillage drag presented above (Figure 2) is minimal and is a result of the most forward ramp creating a shock that is not aligned with the cowl lip. The main reason for this is that the aircraft will spend very little time flying at Mach 2.5. The inlet must be designed to accommodate flow conditions at Mach numbers of 2.5 to 5, meaning that compromises will need to be made. When the vehicle Mach number increases, so does the drag¢ÂÂtherefore, it is more effective to compromise efficiency at lower Mach numbers where drag is relatively low to allow for optimisation of the inlet design for higher Mach numbers. As the Mach number increases, the shock angles will reduce, allowing for better alignment of the shock waves with the cowl lip. Although the aircraft will not cruise at any conditions where the ramjet is the main source of thrust, it is important to maintain an efficient design to achieve the best aerodynamic performance.For lower Mach numbers such as Mach 2.5, the use of three inlet ramps may seem excessive, however to achieve maximum pressure recovery at higher Mach numbers, more oblique shocks are required. There is a possibility to implement a variable geometry inlet into the design, allowing for a more ideal configuration at each Mach number, however this has obvious downsides including added weight, maintenance and it must be rohlem mu odnitimrep ,zupac od oib¡Ãl on riac a ma§Ãemoc euqohc ed sadno sa ,atnemua hcaM ed oremºÃn o euq adidem Ã .]31[sadizuder seµÃssime moc zacife siam amrof ed lev-Âtsubmoc ramieuq arap o§Ãrofse mu me resal a o£Ã§Ãingi ed sametsis odnanoicerid o£Ãtse sorutuf sotejorP .adartne ad ortned sacit¡Ãtse sarutarepmet sad lev¡Ãifnoc elortnoc reuqer sam ,acsÃaf ed sametsis ed edadissecen a zuder ossI .oda§Ãnacla odnes ¡Ãtse euq levÂtsubmoc ed hsalf ed otnop oa odived oxulf ed o£Ãtsubmoc ad medneped tejmar ed sotejorp sod airoiam a siop ,etnatropmi ©Ã ossI .5 arugiF an odartsom omoc ,adartne a arap a§Ãnava euq adidem Â)acimr©Ãt aigrene Â acit©Ãnic aigrene a odnaretla(etnemua oxulf od acit¡Ãtse arutarepmet a euq moc zaf oxulf od o£Ã§Ãarelecased e o£Ãsserpmoc adip¡Ãr A .hcaM oremºÃn odanimreted mu me adauqeda o£Ãsserpmoc recenrof arap sapmar e olucÃev od oproc od edneped tejmar O .odateje e odingi o£Ãtne ©Ã oxulf o edno ,sair¡Ãssecen seµÃsserp sa arap oxulf o rimirpmoc rop lev¡Ãsnopser ©Ã rosserpmoc o ,otaj a rotom mu mE .tejmar ed rotom od oslupmi ed o£Ã§Ãudorp e adauqeda o£Ãtsubmoc a arap air¡Ãssecen ©Ã o£Ãsserpmoc atsE .adartne an artne oxulf o euq adidem Â acit¡Ãtse o£Ãsserp ad otnemua o artsom 5 arugiF A .arietnorf ed e o£Ã§Ãcirf ed adamac ed sotiefe ,euqohc ed sadno sad ortned sadrep ed odatluser ©Ã e laicnatsbus etnatsab o£Ãsserp ed adrep amu ©Ã atsE .%32 ed ©Ã adartne ed o£Ãsserp ed latot adrep a ,5.2 hcaM me euq artsom 4 arugiF a ,]6[me atreboc etnemavisnetxe sapmar sªÃrt ed o£Ã§Ãarugifnoc a odnasU .]21[ohlabart etsed otibm¢Ã od arof mavatse euq ,adartne ad o£Ãsserpmoc ed ametsis od ohnepmesed o erbos ,otnatrop ,e euqohc od o£Ã§Ãazilacol a erbos met ocimÃuqomret oirbÃliuqe-o£Ãn o euq sotiefe sievÃssop so meulcni aicn¢Ãtropmi ed sonem´Ãnef sortuO .]11[sadacifilpmis sacir©Ãmun satnemarref odnasu sodadutse res ,ragul oriemirp me ,medop sonem´Ãnef siaT .tejmarcs olep odanoislupmi odnes ¡Ãtse olucÃev o odnauq 8 hcaM me air¡Ãutroporea agrac a ratropus arap etneicifus o£Ãs o£Ãs euqohc ed sadno sa ,hcaM oremºÃn etseN .)6 arugiF(adartne ad atnagrag ad adÃas Â sanepa odazilacol ¡Ãtse adnia lamron euqohc o euq ©Ã etnatropmi otcepsa o ;adartne ed KCATTA FO ELGNA ni egnah htw htw .esu ni yton tejmar eht nehw rof EPAHS KOMANYDORE REDELS EVRESERP POLEP OT NESOHC EREW SELGNA PMAR REWOLLOLAHS THERE STEP EHS STAHTAH STAHTAH STAHTAH STAHTAH STEP STAHTAH STAHTAH STEP Taht erusne ot tnatropi i ti ,eliforp tgilf eht fo llams ylevitaler ROF LANOIREPE EB LANOREVITALER EB YL THILNO LILNO THIHT .4 hcam to 0l02 FO ecnereffid a ot ecnereffid ecneffid edeffid edeffid edeffed sessarcni sessarcni sessarcni sessaercni sessaercni sessaercni sessaercni sessaercni sessarcni sessaercni sessarcni sessarcni sessaercni yht sessercni sessaercni sessarcni sessarcni sessarcni sessarcni sessarcni sessarcni sessaercni sessarcni; .]4[erutetetil eht Dnuof ,nwohs noititutofnoc â€â€¢€âkcohs euqilbo 3 + Kcohs Lamronâ¸â€â€T detnesserp ehttonesnoc yoht yohtsnoc scitamehcs DFC evoba eht ni nwohs noitarugifnoc pmar-eerht eht htiw dnopserroc 9 erugiF ni deniatbo stluser ehT .snoitidnoc cinosbus ot srebmun hcaM rehgih morf wolf eht gnicuder rof ytlanep a ,sesaercni rebmun hcaM eht sa secuder yrevocer erusserp ehT.06 woleb tsuj sehcaer oitar erusserp Eht ,5 hcam for saerrehw ,01 revo tsuj fo oitar noisserpmoc you ,5.2 hcam .oitar noisserpmoc eht some ,sesercni rebuse hcam sserad siser siser sandah sour sardah Terroc eht ta Wolfria gnidivorp fo tnemeriuqer eht sediseb .snoitiddddded maerts eerf gniyrav to hcam elbatius ot eht ecuder ot. A Htiw etanimret dna tna tna eht nihtiw gnitcelfer era ,rebun hcam saht ta s 7 eht tsuj detacols si lcssa tnatropmi tnatropmi tnatrop tnaeb htropmi. llaf ot nigeb sevaw kcohs eht ,sesaercni rebmun hcaM eht sA.wolf eht etareleced yllaudarg ot spleh dna detcepxe si sihT .kcohs lamron a htiw etanimret dna telni eht nihtiw the airflow into the inlet will experience greater changes in direction in comparison to the aircraft flying level. There is a need to ensure that the shock waves will reliably decelerate the flow while maintaining sufficient airflow into the inlet and not creating additional spillage drag. Since the ramjet is used to accelerate the vehicle to the region of Mach 2.5 to 5 and increase the altitude from 50,000 ft to roughly 80,000 feet, for most of the ramjet flight profile, it will experience positive angles of attack. Furthermore, the air density will decrease as the vehicle gains altitude, bringing many advantages and disadvantages. The reducing air density will reduce the air resistance experienced by the entire vehicle, however, it will also reduce the mass flow rate into the inlet of the ramjet. As the aircraft approaches the engine switch over speed (to the scramjet), there will be a phase where both the ramjet and scramjet will be simultaneously producing thrust for the vehicle. This will help to create additional thrust to counter the high levels of drag experienced as the vehicle enters the hypersonic flight regime. Once the scramjet engine has successfully started, the vehicle will continue to accelerate up until the ramjet no longer becomes advantageous (circa Mach 5). In Figure 10 below, we can see a comparison between the inlet performing at Mach 3 at an angle of attack of 0Â°Â and 3Â°Â. Figure 10b shows that when the airflow approaches the aircraft at 3Â°Â, the shock formation does not differ greatly when compared to the 0Â°Â configuration (Figure 10a). This is a positive result, as it shows that this design is not easily affected by changing flow direction. Changing flow direction can often cause the normal shock within the inlet to become unstable and be ejected out the front of the inlet, causing unstart conditions. In this case, we can see that the normal shock remains within the divergent section of inlet and manages to maintain steady airflow into the combustor. A second test like the one above was performed for Mach 5, again with an AoA of 0Â°Â and 3Â°Â (Figure 11).The main difference between the two angles of attack (Figure 11a,b) are that for a 3Â°Â AoA, the shock waves have a slightly shallower angle which can be explained by the change in airflow direction. The normal shock remains within the diverging section of the inlet and can maintain stability, however, it can be seen to have moved forward slightly in the case of a 3Â°Â AoA. An issue affecting engine inlets is the inevitable presence of an adverse pressure gradient, a result of the increasing static pressure in the direction of the flow. The effect of this is likely to induce additional turbulence within the inlet, boundary layer separation causing poor normal shock stability and ultimately reduced efficiency, and poor performance of the inlet. In order to minimise the effects of the adverse pressure gradient, a series of boundary layer bleed holes can be implemented to help avoid separation from adverse shock waves and boundary layer interactions [15].Figure 12 shows the two boundary layer test setups used to evaluate the influence that bleed holes have on the boundary layer. Reducing the boundary layer thickness, especially in supersonic inlets, is an important aspect that needs to be taken into consideration. Configuration A is the normal, non-bleed setup and Configuration B is the setup containing a basic bleed system. The bleed hole angles have been set up at an angle of 50Â°Â as recommended by the NASA report ¢ÂÂOn Supersonic-Inlet Boundary Layer Bleed Flow¢ÂÂ [16], allowing for an optimal boundary layer capture geometry. A noticeable aspect in Figure 12 is the slight disturbance in the flow just above the bleed system in Configuration B. This indicates that the bleed system has not yet been fully optimised for this configuration. On the other nees eb llits nac kcohs lamron ehT .noitagaporp evaw kcohs eht fo llaw edis tejmar eht fo noitcaretni eht wohs stluser D3 eht,esac D2 eht ni deniatbo stluser eht noitid eht sedivorp 41 erugiF ni noitamrof kcohs eht fo noitasilausiv a sedivorp 41 erugiF ni noitamrof kcohs eht .detciped sa htdiw eht eciwt si ecneh dna ,stnemeriuqer lanoitatupmoc eht sA .derolpxe eb ot dedeen noitarugifnoc D3 a fo ecneulfni eht ,ledom)D2(lanoisnemid-owt gnikrow a dehsilbatse gnivaH .scitsiretcarahc wolf eht no stceffe esrevda srucni hcihw thgieh reyal yradnuob ni ecnereffid eht etartsulli retteb ot sruotnoc hca : : : : : : : : : : : : ; ©Ã :o£Ã§Ãauqe an omret odnuges od s©Ãvarta odaluclac ©Ã MAR ad otsarra O .tejmaR ed adartne ad MAR ad otsarra on adazilaer iof esil¡Ãna amU .hcaM ed roiam oremºÃn mu me sadailpma o£Ãs sadrep sa euq rop etnemlaicnetop odnacilpxe ,adartne an sadrep sartuo odnizudortni D3 airtemoeg ad odatluser zevlat uo acip³Ãrtnesi acir©Ãmun esil¡Ãna an satief seµÃ§Ãisopus ed odatluser res edop sodatluser so ertne aicnªÃreoc ed atlaf A .aigrene levÃnopsid od etrap rirefsnart ed zapac ¡Ãres ³Ãs levÃtsubmoc o ,atla revitse ¡Ãj rotsubmoc on artne euq oxulf od arutarepmet a es ,otnatne on ;oslupmi roiam o rareg arap levÃssop oxulf o arap aigrene ed omix¡Ãm o arifsnart levÃtsubmoc o euq lev¡Ãjesed ©Ã ,etnemlaedI .odamieuq odnes ¡Ãtse euq adidem Â levÃtsubmoc od aigrene sonem ¡Ãrahnag agrac a euq acifingis arutarepmet ed o£Ãzar an otnemua essE .)0T/2T(arutarepmet ed axat Â etnereni otnemua mu ¡Ãrevah ,acit¡Ãtse o£Ãsserp ed axat an otnemua mu moC .o£Ãtsubmoc a s³Ãpa arutarepmet a e rotsubmoc on artne euq agrac ad arutarepmet a ertne o£Ãzar alep odacifitnauq res edop rotom mu ed ovisluporp oslupmi o euqrop ,otnatne on ,acort amu ¡ÃH ;soslupmi ed o£Ã§Ãudorp a arap iubirtnoc siop ,sotla siam HCAM soremºÃn me sair¡Ãssecen o£Ãs o£Ãsserpmoc ed secidnÃ seroiaM .sotla siam hcaM soremºÃn me erroco euq otnemaleporta ed otiefe od otnemua od odatluser ©Ã acit¡Ãtse o£Ãsserp ad otnemua O .s©Ãp 000.05 a e 5 hcaM me tejmaR rotom od ortned acit¡Ãtse o£Ãsserp a artsom b61 arugiF a e sadasu seµÃ§Ãatse sad aicnªÃrefer a ecenrof A61 arugiF A .oir¡Ãssecen oslupmi o rignita arap etneicifus levÃn mu me a§Ãenamrep o£Ãtsubmoc ed aram¢Ãc ad o£Ãsserp a euq laicurc Â .rotom od ocib o ereleca oxulf o euq moc odnezaf ,odamalfni ¡Ãres ele ,o£Ãtsubmoc ed aram¢Ãc an artne oxulf o euq adidem Â .levÃsiv etnemaralc ©Ã atopac ad oib¡Ãl od agaporp es euq euqohc o e adartne ad ortned euqohc ed o£Ãxelfer a edno ,avitanretla o£Ãsiv amu ecenrof 51 arugiF A .air¡Ãssecen o£Ã§Ãarelecased a odnitimrep ,adartne ed atnagrag ad ©Ãr a maramrof that the o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o o Drag (Á¹ 0U0) reduces the total impulse provided by the engine, and as the flight velocity increases, as is the drag of the RAM. The ram input drag calculated in Figure 17 represents both the 2D and 3D ram degred values for the Dado Ramjet project. It is important to mention that ram's drag is just a small component of the drags that will be experienced; The SCRAMJET entrance drag, along with the trawl induced throughout the venacle, will need to be totaled and taken into account. The propulsive impulse of the nozzle will need to be greater than the sum of all the drag components to provide enough enough. RAM 3D drag is considerably larger than 2D RAM. It was assumed that the entrance of Ramjet had a width of three meters (more sizing can be found in Figure 17 below), allowing more three meters wide for the entrance of Scramjet. The reasons for which a total width of six meters was required for engine allocation was due to engines that need to remain within the ends of the aircraft's Mach cone. In the position where the engines would be mounted, the Veanculo had a wing of only six meters, making the decision to it. This configuration may not necessarily be the width of the final project of the aircraft and was used to determine the influence. A chosen ramjet input design scheme is detailed in Figure 18 (supply of ramjet geometry in meters), while Figure 19 shows the influence that the input ramps are in the flow in Mach 2.5. ApãªDex A.2 provides the main geomal properties of the different ramp models. In ramp 1, the flow immediately experiences slowdown, along with a decrease in the total pressure and increased estate. The second ramp (which is in a larger deflex of deflex total and increases static pressure. An anomaly occurs between ramp 3 and normal shock, where the flow MachIt increases momentarily, along with the total pressure, however, also a reduction in the static pressure. This behavior is not ideal, as it increases the amount of slowdown that flow will experience when passing through the normal shock wave. The reasons for increasing the number of Mach is because of the small wave of expansion that can be seen to form in Figure 2, at the bottom in the entrance place. Ideally, the project needs greater optimization to reduce associated losses of expansion. Figure 20 shows a tendency similar to what was experienced in Mach 2.5, however, in a mach flow of $M = 5$, many more losses are present. The first ramp has a mother influence on the Flow Mach 5, however, the influence of RAMP 2 van is a sharp decline in both the number of Mach and a total pressure accompanied by a small increase in the stretch pressure. This tendency remains the normal shock, where the most dramatical changes in the observed flow properties. Table 2 indicates that the number of Mach increases, the efficiency of the input decreases. This table works to ensure that the loss in the recovery of pressure is an inherent result of the increase in the number of free flow mand. There is a potential for a more gradual reduction in the number of Mach, which would perform greater pressure recovery and better press rate values, but this would require a more fundamental look at the optimization problem The entrance, which was outside the present work. Since the Veanle needs to be able to produce impulse when stationary, Ramjet and Scramjet would not be adequate for the aspects of tanxi and discololation of the mission profile. It is here that the use of low bypass turbofan engines will be necessary. Due to the highly aerodinã form of the vehicle and the limited quantity of space to contain the engines, it was opted for an over/under (Figure 21 -configuration (Figure 21 - illustrative purposes - this figure is not to scale). This configuration for the engines to be stored within the vehicle body (minimising drag) as opposed to the typical subsonic aircraft configuration of external nacelles. A benefit of the over/under configuration of the ramjet and turbojet engine is that firstly, the physical separation between the ramjet combustion chamber and turbojet assembly allows for higher temperatures within the ramjet to be reached without damaging the turbojet components, contrary to the wrap around configuration. Secondly, as a result of the inlet ramps, a volume has been created behind the ramps which is ideal for the positioning of the turbojet engines. The alternative use could have been for fuel or cargo storage, but as the turbojets are a necessity, it is obvious that they are the option of choice. The turbojet is required to accelerate the vehicle to Mach 2, as the conditions used for CFD analysis assumes Mach 2 conditions. Figure 22 shows that at this velocity, the ramjet inlet still manages to induce a normal shock just aft of the inlet throat. The turbojet requires subsonic flow conditions to achieve efficient performance and minimise shock damage to the compressor blades. The difficulty at this condition is that without a variable geometry ramp system, the shocks are not ideally aligned with the cowl lip, which will lead to additional drag and minimal shock reflection, ultimately reducing the pressure recovery. The advantage of a turbojet is that its compressors will be able to help overcome pressure issues associated with the losses.In addition to the combined cycle configuration of the turbojet and ramjet, the scramjet will also need to be introduced into the final assembly. To achieve the optimal performance from the engines (both ramjet and scramjet), it was essential that the forebody design would cater to both the ramjet and scramjet inlets. Furthermore, due to the different ramp angles etc., a design that introduced minimal interference The two engines were necessary. One challenge faced was to try to minimize the shock formation resulting from the misalignment of the entrance ramps. In order to provide the necessary impulse, the input area, a fuel and nozzle, must be properly sized. In the effort to preserve symmetry, the decision has been made to put a ramjet on both sides of the Scramjet as seen in Figure 23. Having the engines located under the venacle is advantageous of vain ways: the forebody scree It is able to help in the external compression of the input flow [17]. Wings remain clean, reducing the pylons drag from the outer engine and nacelles wings so small weight, as there is no need for structural support for engines (lower forcens); Reduced structural material leaves space for additional combustible storage the afterbody vehicle can be used in the ramjet and scramjet expansion phase the idea of sharing the combustion of ramjet and scramjet was explored, in the However, the inherently different geomal requirements would impose the need for an inlet throat and nozzle variable geometry. Ramjet requires subscriptions, sending a throat of the beak to reach enough expansion. The scramjet, on the other hand, does not experience the subscription, denying the demand of a throat. In addition, it would be a challenge to optimize the combustion of combination to effectively perform along the wide range of Mach Mach; For example, Ramjet uses flames, which would cause excessive drag for an Scramjet. The main relative questions are implemented by the Ramjet in the hypersanic venicle not emerged with the practitioner, but with the attempt to locate Scramjet and Ramjet alongside each other with their very different nozzle configurations . Figure 24 demonstrates the performance of the combined ram and scramjet jet in Mach 5; Black lines mean otnauqne otnauqne ,tejmar ed red lines indicate the scramjet inlet. The yellow line indicates the location of the normal shock within the ramjet inlet, which can be seen to be just aft of the inlet throat.It can be seen that there exists an area of subsonic flow just forward of the scramjet inlet, which is not ideal. This is caused by the scramjet choking the flow, creating high levels of spillage and ultimately drag; to mitigate this, the use of a deflection ramp to divert flow away from the scramjet inlet could be implemented while the ramjet is in use. In addition, the performance of the ramjet has also been affected; this can be seen by the greater variation in flow speed within the combustor inlet. Previous analysis has shown effective flow control throughout the inlet, however the introduction of the scramjet has influenced the shock waves and flow deceleration has become less steady. This is an adverse effect which may result in an unstable normal shock. The cause of this reduced performance is likely to be a result of the influence of the scramjet¢ÂÂs geometry on the formation of shock waves within the ramjet inlet. Figure 25a provides a front view of the ramjet inlet which was tested using the symmetry line to save on computational demand. A final geometry is represented in Figure 25b, where the two ramjets are located on the outside of the scramjet engine as described in Figure 23. Looking at the ramps of the inlets in Figure 25, it is evident where the shock waves are being formed, made visible by the change in colour representing a change in Mach number. Figure 25c shows the influence that the scramjet has on the shocks of the ramjet. The shock waves are being three-dimensionalised, and originate from the walls of the scramjet. Before, when the shocks fell onto the ramjet inlet, they were straight; now, however, they are at an angle due to shock interference.An additional undesirable characteristic with this configuration is the Height of the engine inputs needed to produce enough impulse. A potential configuration that can deny the above question would be to rotate the two ramjects so that they are essentially mounted to the side, with the first ramp acting as the wall of the Scramjet. Ramjet is likely to be a reduction in Scramjet interference in the shock formation leading to Ramjet's entrance. A potential issue arises, since Ramjet will no longer have a front body to help in compression; All compaction will need to be performed through the ramp system. In addition, the effect of passing the waves will be reduced, as the change of moment in the nearby flow particles will be diverted out, as opposed to downward. A potential advantage of this configuration, in addition to reduced shock interference, is that the hypersonic vehicle can achieve directional stability. A cross-sectional view of the section plan is shown in Figure 27. The incorporation of this project will affect the design of the Over/Under configuration required for the implementation of the TurboJet engines. A CFD analysis carried out in the project shown in Figure 26 confirms that the input system for Ramjet is able to operate throughout the flight profile, as seen in the Mach 5 conditions in Figure 28. In addition, the issue regarding shock interference was mitigated by altering the configuration. This study proposed analyzing the ideal Ramjet input configuration, which would allow a hypersonic vehicle to perform its mission profile, helping to accelerate between Mach 2.5 and Mach 5, after which the Scramjet engine would engage. Ramjet should create sufficient impulse in its given operating conditions, in addition to minimizing the drag of the vehicle when in hypersonic conditions; This resulted in a commitment to performanceto maintain an aerodynamic form. In addition, as the Ramjet is used only for a small fraction of the mission profile, it was decided that for this investigation, a non-variable geometry input would be used. The main reason for this is that variable geometry mechanisms increase weight, especially when they need to tolerate such an extreme air load; The additional weight would work to reduce efficiency on high cruise mach. The overall performance of the Ramjet compression system became progressively poorer with the increase of the Mach number, ranging from approximately 80% of pressure recovery in Mach 2 to 35% of pressure recovery in Mach 5; This could potentially benefit from a variable geometry input. That being said, the Ramjet reaches subsonic flow conditions within the combustion chamber, along with sufficient increases in pressure and static temperature. Validation through numerical analysis and comparisons with previous literature indicates that Ramjet input maintains reliable and consistent results, however, the final integration of the entire engine remains questionable due to the lack of literature on the complete performance of the Ramjet engine. In addition, the implementation of the Ramjet input for the remainder of the Ramjet engine led to challenges, including stabilization of the back pressure; In addition, the introduction of combustion in simulation led to other challenges in relation to the convergence and reliability of the results. Several input mounting settings have been explored Ramjet adjacent to Scramjet, with the main issues assigned to the formation of new shock waves of interference. This was overcome by rotating the Ramjets 90 ° to allow the first Ramjet ramp to act as the Scramjet sidewall. This configuration led to a more uniform formation of shock waves, along with a slight reduction in engine weight due to the odanibmoc odanibmoc od o£Ã§Ãargetni A .tejmarcS od ederap ad lairetam od The engine configuration in the vehicle itself presented new challenges, including the combination of different CFD models that were used for different reasons over individual tests, i.e. Spalart-Allmaras vs. K-Omega vs. K-epsilon. Gathering all sections and having to perform a design that was optimized using a specific model led to the issue of the results that vary from what was expected. In conclusion, the Ramjet compression system managed to perform reliably, but would benefit from additional optimization. A.P. conceived and designed the experiments and presented the ideas of research concept behind the project; S.V. performed the experiments, analyzed the data and wrote the first draft. L.G. contributed to the methodology, technical research and supported by the provision of the relevant background theory. This research did not receive external funding. The authors declare no conflict of interest. The test conditions were defined in Mach 4 with a static pressure at the entrance of 7378 Pa. The main difference between the configuration in this report is that this mesh had 190,000 elements compared to the 14.99 million elements used in the report mentioned above (7). The use of 190,000 elements was justified by the limited computational resources available and the study of convergence of Illustrated mesh below in Figure A1, which shows that, after 190,000 elements, there were no significant changes in the results. The test area was decided to be at a point directly behind the normal shock formed in the incoming throat. Figure A1. Number comparison Normal shock Mach Aft. Figure A1. Number comparison Normal shock Mach Aft. Figure A2 displays the scheme of an external two-lane compression system with deflection angles for the first and second ramp of 9 ° and 11.5 ° respectively. The length of the flat surface under the bodyvenacle and the horizontal length of the ramps was defined as 35 m to allow development development the border layer. However, the exact distance of the flat surface does not make a lot of differences as long as the flow is parallel to the horizontal plane. Figure A2. Two people of ramp entry (dimensions in meters). Figure A2. Two people of ramp entry (dimensions in meters). Tracks were performed to identify the time performance of a Scramjet input; Table A1 presents some of the important values, such as compression and the recovery of pressure obtained from the two -ramp system. All crash waves are numbered from 1 to 5 in the columns of Mach Mach in Table A1, Table A2 and Table A3 below for the increasing manner of shock waves found with two -ramp input configurations and four ramps. . Table A1. Terraculum for two ramp entrances. Table A1. Terraculum for two ramp entrances. M1M2M3 Compression Relationship (PRAT) Recovery of Pressman (Prec) temperature increase (ï †) 4,003,362,715,650,704,742,996,730,841,815,004,004,257,980,801. 93 Figure A3 describes the scheme of an entry project of TRANS RAMPS with deflections £ o „îti = 9.5â °, îta2 = 9.5â ° and îta3 = 9.5, °; Having the same deflex to all ramps allows the best prescription recovery. Figure A3. TRANSLY FORGETTING RAMP INPUT (DIMENSION IN METERS). Figure A3. TRANSLY FORGETTING RAMP INPUT (DIMENSION IN METERS). Table A2 presents the told of the downstream, compressive, compressive, recovery of pressure, increased static temperature and advanced efficiency in a variety of speeds of Free flow flow flow. As can be seen in Mach 8, the flow should slow down to Mach 3,788 after the final shock wave, which reaches a compressive and recovery relationship of 44.54 and a recovery of 44.54 and 0.52, respectively. Table A2. TREATIC CLASSES FOR TRANSE RAMP INPUTS. Table A2. Tenticities for ramp entrances. Compression ratio M1M2M3M4 (PRAT) Figure A4 shows the scheme of an inlet project of four ramps with angles of deflection 1 = 8 °, Ĩ 2 = 8 °, Ĩ 3 = 8 ° and î4 = 4.5 °; These values were selected to compare the difference in performance, with the same total angle of deflection as the three branched. In Mach 8, the compression ratio reached is 47.05, the pressure recovery is 62.5% and the temperature increase rate is 3.489. The compression ratio and recovery of stagnation pressure achieved is better than the input of three ramps with total deflection (the input of three ramps has Prat = 44.54 and Prec = 52%). Figure A4. Four schematics of ramp entry (dimensions in meters). Figure A4. Four schematics of ramp entry (dimensions in meters). Table A3. Theoretical calculations for four ramp entries. Table A3. Theoretical calculations for four ramp entries. M1M2M3M4M5Compression Ratio (Prat)Pressure Recovery (Prec)Temperature Increase (ICE)4.003.432.962.572.439.790.911.974.503.823.282.842.6912.240.882.125.004.23.583.092.9315.2204303.823 In Anais of the 44th Meeting and Exhibition of Aerospace Sciences of AIAA, Reno, Nevada, 9 - 12 January 2006. [Google Scholar] Berry, S.; Daryabeigi, K.; Wurster, K. Transition of the boundary layer in the X-43A. J. Spacecr. Rocket. 2010, 47, 922 - 934. [Google Scholar] [CrossRef] [Green Version] Sziroczak, D.; Smith, H. A review of specific design issues for hypersonic flight vehicles. Prog. Aeroesp. Sci. 2016, 84, 1 28. [Google Scholar] [CrossRef] Fry, R.S. A century of evolution of Ramjet propulsion technology. J. Propuls. Power 2004, 20, 27 - 58. [Google Scholar] [CrossRef] Curran, E.T. Scramjet engines: the first forty years. J. 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Figure 14. Three-dimensional shock visualization (3D). Figure 14. Three-dimensional shock (3D) (3D) Figure 15. Alternate view of 3D Mach contours. Figure 15. Alternate view of 3D Mach contours. Figure 16. (a) Flow stations in a ramjet engine and (b) 3D static pressure contours (Pa). Figure 16. (a) Flow stations in a ramjet engine and (b) 3D static pressure contours (Pa). Figure 17. Pressure recovery comparison. Figure 17. Pressure recovery comparison. Figure 18. Ramjet inlet schematic. Figure 18. Ramjet inlet schematic. Figure 19. Performance of ramjet inlet at Mach 2.5 (50,000 ft). Figure 19. Performance of ramjet inlet at Mach 2.5 (50,000 ft). Figure 20. Performance of ramjet inlet at Mach 5.0 (50,000 ft). Figure 20. Performance of ramjet inlet at Mach 5.0 (50,000 ft). Figure 21. Over/under combined cycle engine investigation. Figure 21. Over/under combined cycle engine investigation. Figure 22. Over/under combined cycle engine Mach contours. Figure 22. Over/under combined cycle engine Mach contours. Figure 23. Side and front view of the hypersonic vehicle. Figure 23. Side and front view of the hypersonic vehicle. Figure 24. Three-dimensional analysis of the ramjet and scramjet (Mach number). Figure 24. Three-dimensional analysis of the ramjet and scramjet (Mach number). Figure 25. Ramjet and scramjet (a,b) full front view with (c) shock angle detail. Figure 25. Ramjet and scramjet (a,b) full front view with (c) shock angle detail. Figure 26. Rotated ramjet configuration. Figure 26. Rotated ramjet configuration. Figure 27. Top view of engine cross section. Figure 27. Top view of engine cross section. Figure 28. Mach contours for alternative combined cycle engine design. Figure 28. Mach contours for alternative combined cycle engine design. Table 1. Concept aircraft target flight profile. Table 1. Concept aircraft target flight profile. PhaseDescriptionAltitude (ft)MachTurbojetRamjetScramjet1Take-off and initial climb0¢ÃÂÂ15000 to 12Climb 11500¢ÃÂÂ40,0001 to 23Climb 240,000¢ÃÂÂ60,0002 to 44Climb 360,000¢ÃÂÂ100,0004 /0.4/yb/sesecil/gro.snommocevitaerc//:pth(.)/ 0.4/yb/sesecil/grim HCAM TNEREFFFID TECNEICFFE TELNI .2 ELBAT ONITREPO ONTOITREPO Laudnoitarepo Elgnis800,0

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