Chapter I-2: The Integrated Land and Air Resource Model

The purpose of this chapter is twofold: firstly to summaries what an 'integrated resource model' is and why it is essential to obtaining historical accuracy when simulating a large and complex military campaign, and secondly to define the structure, concepts and terms used to build a complete mathematical model representing a country's war effort.

What is an Integrated Land and Air Resource Model?

The model principles described in this chapter are not concerned with the detail structure of the armed forces in question (this will come later), but are concerned with how we can model (or simulate) the creation and flow of personnel and equipment from mobilisation and manufacture, to loss from combat and attrition. For our purposes, this mass of personnel and equipment (vehicles, weapons and squads) will hence be termed 'resources'.

Therefore an Integrated Land and Air Resource Model can be defined as: **a complete mathematical model representing a country's war effort, which enables the creation and flow of all (war related) resources to be continuously tracked from mobilisation and manufacture, to loss from combat and attrition.**

Part II of this book, titled 'The Barbarossa Simulation's Resource Database', focuses on determining what resources will be included in the model, and the relevant attributes relating to each type of resource. Part II analyses the physics of the vehicles, weapons and squad types (all types of resource) involved in the Integrated Land and Air Resource Model. It describes how the 'combat power' and 'specific combat attributes' of individual resource types are calculated.

The Underlying Principles

There are two fundamental principles that form the foundation of the Integrated Land and Air Resource Model, and to which the model must adhere at all times. These are:

The conservation of resources.

The 'conservation of resources' principle is similar to the 'conservation of mass' principle in physics. In this case the 'mass' is defined as the resources (personnel and equipment) involved. The conservation of resources principle dictates that resources cannot be created from nothing and they cannot disappear, unless destroyed or scrapped. This initially sounds obvious because the concept is simple. In fact adhering to the principle of conservation of resources is difficult to achieve in practice. It means that all personnel (initially available and newly mobilised), and all equipment (initially available, newly manufactured, and commandeered), has to be continually tracked within the model from manufacture and deployment to the end of its service life, or to the end of the period in question.

The model is an interactive 'system'.

The term 'Integrated' in the model title refers to the fact that the model is a complex interactive system. This means that any change in any part of the model (or system) has a direct cascade effect on many other model components.

For example, if fewer resources such as trucks are allocated as replacements to deployed combat units, then more trucks are available for newly mobilised units and support infrastructures. Improved support infrastructure results in a better overall Supply Distribution Efficiency (SDE). The net result is that older deployed units are less mobile, while new units are more mobile and all units get supplied more efficiently (higher SDE).

Another example is, if the Soviets lose even more divisions in June-July 1941 than was historically the case (in the Operation Barbarossa simulation), then the massive influx of newly

mobilised replacements will be diverted to newly mobilised divisions, making them stronger quicker. If the Soviets lose fewer divisions in June-July 1941 than was historically the case, then the divisions deployed on 22nd of June 1941 will have more time to get closer to their full strength, while the newly mobilised divisions will take longer to get to their full strength.

It goes without saying that without the power of modern computers, it would be almost impossible to create a practical integrated resource model of a county's war effort that conformed to the two principles above: even a military simulation of a relatively small battle would be difficult and largely impractical.

There are two types of integrated resource model used in 'Operation Barbarossa: the Complete Military Simulation', namely the Fully and Partially Integrated Resource Model.

The Fully Integrated Land and Air Resource Model (FILARM)

In the FILARM model, all resources present at the start of the campaign, and all resources received from all sources during the campaign period, are modelled.

'Fully' refers to the fact that all resources, in all physical locations (i.e. all fronts) are included, and not only those on the Eastern Front (Axis) or Western Front (Soviet).

Obviously the countries of primary concern in Operation Barbarossa are Germany and the Soviet Union. For these countries Fully Integrated Land and Air Resource Models (FILARMs) are used. The FILARM model is also used if the bulk of a county's armed force was committed to support Operation Barbarossa in 1941. This includes all Finnish forces, the Hungarian Air Force and the Rumanian Air Force (refer to table below).

Given that Operation Barbarossa was the largest invasion in history, leading to the largest and bloodiest military campaign ever recorded, I'm sure the reader will understand that creating Fully Integrated Land and Air Resource Models for the main belligerents is a massive undertaking. It is inevitable that some components of the respective FILARM models will need revising and updating as more accurate historical information becomes available. However these updates will be relatively minor in the overall scheme of the military simulation and historical context. Today sufficient archival information is available to build accurate FILARM models for Operation Barbarossa, with all the key military, economic and environmental parameters included.

Partially Integrated Land and Air Resource Model (PILARM)

In the PILARM model, all resources allocated to East Front forces present at the start of the campaign, and all resources received by forces on the East Front during the campaign period, are within the model.

'Partially' refers to the fact that only resources allocated to the East Front are included. The East Front in this case is defined as: forces entering the Soviet Union after 22nd of June 1941, or which were made available by the relevant command to enter after that date. Note, some minor Axis Allied forces were made available to the relevant commands in 1941, but did not actually enter the Soviet Union.

A Partially Integrated Land and Air Models (PILARM) is used for most of the Slovakian, Hungarian, Rumanian and Italian forces committed to support Operation Barbarossa in 1941 (refer to table below). The Hungarian and Rumanian Air forces are the exceptions.

Naval Forces Involved in Operation Barbarossa

At this point it is necessary to mention the naval forces involved in Operation Barbarossa, and how they fit into the Integrated Land and Air Resource Models.

Although the naval forces were relatively small compared to other naval theatres in WWII, they were still significant and carried out some major operations. These were mainly evacuating or

supplying port cities such as Odessa, Riga and Tallinn. The evacuation of Tallinn by the Soviet Baltic Red Banner Fleet was a particularly large naval operation in 1941.[1] The successful Soviet evacuations of Odessa and the Hango peninsula garrison in 1941 are also noteworthy naval operations. The only amphibious landing operation in the Baltic Sea in 1941, which could be considered large scale, was the German operation *Beowulf*. This involved the invasion of the Saaremaa (Osel) and Hiiumaa (Dago) islands in the Baltic, by the 61st Infantry Division and support units, from the 14th September to 21st October 1941.[2] The most significant amphibious landing operation in the Black Sea was the Soviet landings on the Kerch peninsula in late December 1941.[3]

The various combatant's naval forces are not 'fully integrated' into the Fully Integrated Land and Air Resource Model (FILARM). This is because the seagoing personnel, smaller pieces of equipment, and dockyard supply and repair infrastructures are not tracked in the naval models. Hence naval personnel and equipment should be seen as additional to those in the FILARM model, with the exception of naval personnel that became naval infantry and fought as ground troops, and all land based naval aircraft. The later two are all included in the FILARM models. This is particularly significant for the Soviets because all aircraft in the Soviet VVS-SF (Northern Fleet), VVS-KBF (Red Banner Baltic Fleet) and VVS-ChF (Black Sea Fleet) are all included in the Soviet FILARM model. These were all significant land based naval air forces, and were primarily involved in air to air and air to ground combat during Operation Barbarossa.

In fact the most significant naval contribution to the Soviet-German war in 1941 did not take the form of ships or naval operations at all. It was the 146 899 Soviet naval personnel that transferred to the Red Army in the form of naval infantry in the second half of 1941.[4] In all, 389 975 Soviet naval personnel were transferred to the Red Army ground forces in WWII. In 1941-42 alone, 21 naval infantry and 30 naval rifle brigades went into the front lines against the Axis armies. The Soviet naval personnel transferred to the Red Army, and the formation of all naval infantry and naval rifle brigades in 1941, are included as land forces in the Soviet FILAM model.

Although the naval forces are not fully integrated into the FILARM and PILARM models, the waterborne components of all the naval and river forces involved in Operation Barbarossa are included in the Barbarossa simulation. Where the majority of a county's naval forces were available to support Operation Barbarossa then all that country's major warships are shown in the naval model. In this case the naval model is referred to as a Full (F) model. Where only a minor portion of a country's naval forces were available to support Operation Barbarossa then only the available ships are shown. This is referred to as a Partial (P) naval model. The most powerful navy involved in Operation Barbarossa was the German Navy, but they committed relatively few forces to support Barbarossa (thus a Partial (P) model is used) because they were busy fighting the Royal Navy at the time.[5]

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[1] This occurred in 2 great convoys around the 26th of August 1941. The two convoys had 84 and 78 ships (including the cruiser Kirov and 18 destroyers of all types). They evacuated approximately 30 000 men, but left around 11 500 to their fate. The operation was very expensive in terms of ships and loss of life at sea. Losses amounted to 5 destroyers and 41 other ships, with the Kirov and many others damaged.

[2] For this operation the Germans assembled around 100 ships and 180 'assault boats'. The entire Soviet Garrison was lost, approximately 15 300 captured and 4 700 killed, with all heavy guns. German killed, wounded and missing were reported at 2 850. Barbarossa, Army Group North 1941, GMT, Hanford CA, 2000, Scenario outcomes, p. 19.

[3] On the night of 25-26th December 1941, the Soviets attempted 25 separate landings in 10 different areas of the Kerch peninsula (only 4 landings were successful). From the 28th to 31st December 1941, 40 000 Red Army troops stormed and occupied the port of Feodosiya on the Crimea's southern coast. The Oxford Companion to WWII, Oxford University Press, New York, 2001, p. 107.

[4] C. C. Sharp, 'Red Death': Soviet Mountain, Naval, NKVD, and Allied Divisions and Brigades, 1941 to 1945, Soviet Order of Battle WWII: Volume VII, George F. Nafziger, West Chester, OH, 1995, p. 28.

[5] For example, only 5 U Boats were initially made available, while the Admiral Scheer and Tirpitz were the only capital ships made available to the Baltic Fleet (*Baltenflotte)* for a very short time in September 1941. H. Boog, et al. (German

The following table is a summary of the type of model employed in the Operation Barbarossa simulation, for each of the combatant's land, air and naval forces.

	Land	Air	Sea
Soviet	FILARM	FILARM	F
German	FILARM	FILARM	P
Finnish	FILARM	FILARM	F
Slovakian	PILARM	PILARM	F^
Hungarian	PILARM	FILARM	N/A
Rumanian	PILARM	FILARM	F
Italian	PILARM	PILARM	N/A
Bulgarian	N/A*	N/A	F**

* N/A Not applicable, no significant forces committed

^ Part of German Danube Flotilla

** Part of Axis naval forces in Black Sea

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The Objectives of the Integrated Land and Air Resource Model

You may ask, "Why is such a comprehensive model necessary"? The reasons are related to achieving historical accuracy and can be summarised by the following:

The Strategic Context of the Military Campaign: Bottlenecks in the Mobilisation Process

An Integrated Land and Air Resource Model enables a full analysis of the belligerent's economic and logistical capabilities, as related to a specific military campaign and in the (strategic) context of their overall war effort. In addition it enables bottlenecks in the war mobilisation process to be determined, and highlights the practical and logistical limits on the size of any operational field army.

The Fully Integrated Land and Air Resource Model (FILARM) is essentially a study of the flow of manpower and different types of equipment, and how they merge together. As such it is possible for a country to strategically have too much of one resource and insufficient of another, resulting in the inability to produce combat and support units of a certain type. The following examples serve to demonstrate some 'bottlenecks' in the various mobilisation processes during Operation Barbarossa, and why a Fully Integrated Resource Model is needed to accurately determine the extent of these bottlenecks.

The Soviets may have actually over-mobilised in 1941. Between 22nd June and the 31st December 1941, the Soviets called up 5 500 000 reservists and conscripts into active service. In addition another 4 000 000 men and women 'volunteered' for militia or volunteer units, and most of these ended up in the Red Army.[6] Unfortunately, approximately 500 000 reservists were apparently

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Research Institute for Military History at Potsdam), Germany and the Second World War, Volume IV: The Attack on the Soviet Union, Oxford University Press, New York, 1996, pp. 376-384.

[6] C.C. Sharp, 'Red Tide': Soviet Rifle Divisions Formed From June to December 1941, Soviet Order of Battle World War II: Volume IX, George F. Nafziger, West Chester, OH, 1996, pp. 2 and 3. This figure may have been as high as 10 000 000. D.M. Glantz, Stumbling Colossus, University Press of Kansas, Lawrence, Kansas, 1998, p. 298, note 11. Also C. C. Sharp, 'Red Volunteers': Soviet Militia Units, Rifle and Ski Brigades 1941-1945, Soviet Order of Battle WWII: Volume XI, George F. Nafziger, West Chester, OH, 1996, p. 1.

taken prisoner before being taken on strength.[7] With this almost unlimited supply of personnel, the major bottleneck on Soviet mobilisation was the availability of equipment, and the ability to supply and support such a large force in the field. This is demonstrated by the fact that only about 2 000 000 (out of 4 000 000) people actually joined the fighting troops, (in operational fronts or armies), via the people's militia.[8] This possible over-mobilisation (i.e. excessive personnel and correspondingly insufficient weapons and transports) resulted in many new combat units of very dubious combat value whilst simultaneously having a detrimental effect on the Soviet's war economy. The combat units of questionable value included militia fighter battalions and most of the separate Red Army rifle brigades. These units had little heavy equipment, almost no transport and support systems, and even less training. However the Soviet mobilisation process did result in a great many combat units of this type, so provided the human cost in casualties could be endured, it is debatable whether the term 'over-mobilisation' is appropriate.

In addition, the FILARM model serves to demonstrate why a massive army in the field, containing a huge number of combat units without adequate support infrastructures, can actually reduce the force's overall Supply Distribution Efficiency (SDE). All combat units in the field still have to be fed, clothed, sheltered, equipped, maintained, refuelled and resupplied etc, regardless of size and combat value. The larger the army in the field at any point in time, the greater the demand on supply and support infrastructures. It should be remembered that as soon as mobilised personnel don a uniform and enter training, they are no longer producing goods or remain self supporting: they have to be supported by the resultant reduced war economy and whatever transport systems exist. The Red Army faced this problem for most of WWII and particularly in 1941, despite large numbers of transport vehicles being commandeered from civilian use. The main reason the Soviet Army's SDE didn't simply collapse in 1941, is that the actual army in the field (being continuously supplied) remained at around 4-5 000 000 and never grew to twice that size. This was because the mobilisation of new units and replacements barely kept up to the staggering losses through 1941. The Soviets admit to 4 473 820 casualties in 1941 from all causes, although this appears to be a low figure as discussed in Appendix B.[9]

The true extent of the personnel vs. equipment bottleneck in the USSR in 1941 only becomes apparent from the Soviet FILARM model. The model clearly demonstrates that the brake on the Soviet mobilisation rate in 1941, and its ability to support such a massive army in the field, was limited by available equipment (including transport). This was the case even though the Red Army and Red Air Force (VVS) enjoyed by far the largest stockpile of weapons in the world in June 1941. Even more importantly, the FILARM model enables us to quantify this effect in any military simulation.

To a large extent the bottlenecks in the German mobilisation process were the opposite to that of the Soviets. Because the Germans under-mobilised immediately prior to Operation Barbarossa, their mobilisation rate in 1941 was limited more by the availability of trained personnel than by availability of equipment. The German figures show that in certain weapon areas they had more equipment available, either stockpiled or in production, than was used in either Operation Barbarossa or on other fronts at that time. Post-WWII accounts usually focus on the low German production figures for 1941 and 1942, to illustrate the lack of clear strategic thinking and planning in the German war economy. Germany (at war since 1939) was at war with the USSR, USA and the entire British Empire, and was suppressing most of Europe by the end of 1941. Yet, German production didn't get onto a war footing until 1943, just a little too late!

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[7] G.F. Krivosheev, et al, Soviet Casualties and Combat Losses in the Twentieth Century, ed. Colonel General G.F. Krivosheev, Greenhill Books, London, 1997, p. 9, table A.
[8] G.F. Krivosheev, et al, Soviet Casualties and Combat Losses in the Twentieth Century, ed. Colonel General G.F. Krivosheev, Greenhill Books, London, 1997, p. 229.
[9] G.F. Krivosheev, et al, Soviet Casualties and Combat Losses in the Twentieth Century, ed. Colonel General G.F. Krivosheev, Greenhill Books, London, 1997, p. 97, table 69.

Nevertheless, German war production was significant and the German FILARM model shows that (for whatever reasons) they didn't release what they had to the Wehrmacht forces on the Eastern Front in 1941. These figures are especially glaring in relation to tanks and assault guns. Almost certainly the same apparent over confidence caused the German war planners to underestimate the personnel replacements which would be needed for Operation Barbarossa. The Germans planned 475 000 Army and Luftwaffe replacements for the first three months of Operation Barbarossa, by which time most senior German officers and leaders assumed the USSR would be on the verge of collapse or already conquered.[10] Unfortunately for the Axis powers, the casualty estimate was quiet accurate but the Red Army was still far from collapse by October 1941. The Germans had suffered 559 994 casualties, from all causes, by the end of September 1941 and 839 855 by the end of 1941.[11]

During 1941 the Germans generally sent replacement to the front after they had been properly trained in army replacement battalions. This meant the German army replacements were trained to a much higher standard than their Soviets counterparts, but there were far fewer of them. The longer training period also meant that there was a considerable delay between the German command belatedly realising that more replacements were desperately needed, and their arrival at the front. The result was that most of the newly mobilised German replacements arrived after 1941, and the German replacements in the German FILARM model are limited to the trained personnel that were historically available. In this case the German FILARM model serves to underscore the failure of contingency planning at the strategic level in the German High Command in 1941.

In conclusion, unless a Fully Integrated Resource Model (which includes all available personnel and equipment) is used as the foundation of any military simulation the size of Operation Barbarossa, it becomes almost impossible to quantify the various constraints and limitations on the combatant's mobilisation processes. It becomes very difficult and impractical to accurately quantify the total resources available to reinforcements, replacements and any supporting infrastructures. In simulations without a Fully Integrated Resource Model, the simulation designer or author is reduced to making an educated guess. This is the key difference between qualitative comments on military history and a quantitative analysis.

Finally it should be noted that the Fully Integrated Resource Model is especially powerful and successful when most of a country's war economy and resources are thrown into a particular campaign. In Operation Barbarossa this applied to the Soviet Union and Finland, and to a lesser extent to Germany. This will become readily apparent to the reader upon examining the respective FILARM model data in detail.

The Actual Personnel and Equipment Present

An Integrated Land and Air Resource Model ensures the ACTUAL personnel and equipment present in all combat units (from large divisions to small corps units) are accurately represented, and not simply represented by the unit's official Table of Organisation and Equipment (TOE).

In any military simulation claiming to be realistic and historically accurate, the actual personnel and equipment present in any combat unit must be used to calculate the maximum combat power of that unit at that time. The actual personnel and equipment present is used in conjunction with other factors such as Relative Overall Combat Proficiency (ROCP) and Supply Distribution Efficiency (SDE).

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[10] H. Boog, et al, (German Research Institute for Military history at Potsdam), Germany and the Second World War, Volume IV: The Attack on the Soviet Union. Oxford University Press, New York, 1996, p.317. Also, R.H.S. Stolfi, Hitler's Panzers East, University of Oklahoma Press, Norman and London, 1991, p. 155.

[11] R. Kershaw, War Without Garlands: Operation Barbarossa 1941/42, Ian Allan Publishing, Shepperton, UK, 2000, appendices 1, p. 251.

Historically, very few countries had sufficient trained personnel and equipment to meet all the demands placed on their armed services. The army would generally issue TOEs it believed were required to do the job, as well as having some chance of being fulfilled with the available resources. Even in peacetime, the actual personnel and equipment available was usually considerably lower than the TOE in most combat units, and after hostilities started this difference often became extreme. In actuality newly mobilised units were often thrown together with ad hoc equipment from various sources including obsolete weapons from old stock, equipment from disbanded units, and newly manufactured equipment.

Many military simulations base the calculated combat strength on TOE (as this is usually readily available through records) and it is obvious why this is a mistake if historical accuracy is the aim. For example, if Soviet divisions in an Operation Barbarossa simulation are simply given sufficient equipment to meet there TOE, then the Soviet FILARM model shows us that the simulated Red Army contains far more equipment than existed in the entire USSR from 22nd June to the end of December 1941.[12]

Combat units did occasionally reach or even exceed their TOE in WWII. However this was usually at the start of a major campaign, and was due to the stockpiling of weapons, transport and supplies before combat operations started. For example, many German units on the East Front on 22nd June 1941 were close to their TOEs, and several Western Allied units before D Day (6th June 1944) were actually well over their TOEs.

Combat Unit Mobility

An Integrated Land and Air Resource Model enables an accurate calculation of the actual mobility of combat units on the battlefield.

The mobility of combat units on the battlefield is directly related to the actual equipment present in any particular unit.

It should be remembered that divisions were (and still are) usually the smallest self contained combined arms units on the battlefield. They normally included infantry, artillery, combat engineers, signal units, and all the supply and support infrastructures required for the division to be self supporting and to operate independently. The TOE of any division was generally calculated with sufficient transport (including horse drawn transport) to be able to 'lift' and move the entire division, including any support infrastructures. This was the case unless the division was specifically designed for a static defence role, such as a fortification unit or a coast defence static division. Some divisions were designated to receive additional transport when the unit was expected to move, but such units tended to be rare: usually, they were either special units (such as airborne units) or the higher headquarters was husbanding their transport resources.[13]

If a division's actual transport strength was well below its TOE strength, then its mobility was much more restricted then if it was at its full transport TOE strength. Without adequate transport available, divisions were unable to fully utilise their disparate sub-units. A division was generally unable to move and fight as a complete unit and it struggled to act independently of other combat units. In other words it was much less able to function as a self contained combined arms unit. The division's actual mobility was critical in battle, and in many cases the heavy equipment was left behind either permanently (if in retreat) or temporarily (if advancing rapidly).

[12] Refer to Part I 8. - 'Military Simulations, and The General Structure of the Integrated Land and Air Resource Model - The Heterogeneous Model vs. the Homogeneous Model', for details on the methods used to establish the actual personnel and equipment in combat units, within the FILARM model.
[13] An example of 'husbanding transport resources', was the Italian 9th 'Pasubio' and 52nd 'Torino' (Semi-Motorised) Infantry Divisions, committed to support Operation Barbarossa from July 1941.

Transport in Operation Barbarossa involved horses with wagons and carts (lots of them!), trucks, light transport, motorcycles and prime movers (tractors and halftracks). Each of the major combatants involved in Operation Barbarossa had different transport TOEs, vastly different available transport and hence widely varying 'mobility factors'. Thus two horse-drawn infantry divisions from different countries may look similar organisationally, but that doesn't mean they had anything like the same actual battlefield mobility. Unless the actual transport available to the various combatants is carefully simulated (as is the case using the FILARM model), a military simulation has little hope of reproducing the actual combat unit mobility or the real circumstances of a battle or campaign.[14]

Efficiency of Supporting Infrastructures

An Integrated Land and Air Resource Model enables an accurate calculation of the maximum efficiency of any supporting infrastructures.

This is the so called Supply Distribution Efficiency (SDE), discussed in detail later.[15]

A combatant's SDE was vital to sustaining prolonged combat operations, and was especially important in any mobile operations. The SDE calculation includes the combat unit's internal support infrastructures (eg, the divisional support elements within all participating divisions) as well as any corps and army level support infrastructures. If the trucks, tractors and other support equipment were never manufactured and never received by an armed force, then the supply and support available to that force was dramatically reduced. This effect has to be quantified carefully for each army and air force because it can decide the outcome of any given battle or campaign before it even starts.

In the first months of Operation Barbarossa, both sides had massive supply and support problems. The Germans were continuously conducting mobile operations, which require more than a basic support infrastructure. They were doing this as their supply lines grew longer along bad roads, and (temporarily at least) further away from their supply railheads. Therefore the available motorised transport, and the railroad construction and operation units, were critical to their operations.

The Soviets suffered a chronic shortage of almost all types of transport. They were closer to their supply sources and railheads and could stockpile more supplies in static defences. However their mobility was limited and they had a massive amount of heavy equipment (considerably more tanks and heavy guns than the Axis forces), which needed even more support than usual. Also, the Red Army had to scrape together sufficient transport to launch more than token counter-attacks (with their large mechanised corps) in order to avoid simply responding to the Axis offensive initiatives.

The FILARM structure enables the SDE of the Soviet and Axis forces to be accurately ascertained, without which any realistic military simulation is severely compromised.

Replacements

An Integrated Land and Air Resource Model enables the number and type of replacements available during a campaign to be ascertained, as well as the replacement distribution.

[14] The mobility of large units is handled in computer simulations using the movement of 'the centre of gravity' of the unit. Refer Part I 5. – 'Military Simulations, and the General Structure of the Integrated Land and Air Resource Model - Military Simulation Concepts and Definitions'.

[15] Refer Part I 9. – 'Military Simulations, and the General Structure of the Integrated Land and Air Resource Model - Supply Distribution Efficiency (SDE)'. Also refer to the relevant sections of Part IV and V: the SDE sections in the Soviet and German FILARM models.

In many military campaigns (not least Operation Barbarossa) the outcome was largely affected by the replacements received by combat and support units during the campaign. Replacements represent the movement of trained personnel and equipment into combat units in an effort to replace those lost, primarily due to combat. Personnel replacements can take the form of infantry squads, personnel crewing heavy weapons, and personnel going into support infrastructure. Equipment replacements take the form of weapons, transport and any other equipment listed in a unit's TOE.

The Integrated Land and Air Resource Model enables the total number of available personnel and equipment replacements to be ascertained, and it enables the distribution of replacements to be determined based on the usage of personnel in the overall war effort. For example, if 70 000 trained infantry replacements and 30 000 trained artillery replacements were available over a given time period, but only 10 000 artillery replacements were required because insufficient artillery pieces were available, then a maximum of 90 000 infantry type replacements (including 20 000 less well trained) were actually available provided there was adequate numbers of small arms available to equip them all. Generally, the combat units in question attempted to rebuild their organisations according to the current authorised TOE. Overall replacement strategy was determined by the resources available, the political culture, and the relevant high command's doctrine and strategic plans.

In 1941 the Soviet strategic planners rapidly realised they were in a fight for their lives and the Soviet Union mobilised for total war very early in the campaign. During Operation Barbarossa the Soviets directed the majority of their resources into creating new combat units, but they also mobilised massive numbers of troops as replacements, mainly in the form of rifle troops with little or even no training. As such, the Soviet Fully Integrated Land and Air Resource Model is critical in determining the maximum personnel and equipment used by newly mobilised combat units, while simultaneously determining the actual resources that were available for use as replacements in existing units. The model tends to highlight the true extent of the Soviet war mobilisation, but it also underscores weaknesses in the newly mobilised Red Army which could potentially have proved fatal to the USSR in 1941.

The Wehrmacht had calculated (many would say gambled) that the campaign in the East would be of a short duration. Examination of monthly listed force strengths (personnel) reveals that their replacements and reinforcements kept pace with losses for most of 1941. However the Germans only had sufficient replacements in the form of trained personnel to maintain their critical attack units, particularly panzer and motorised divisions, near their TOEs until September-October 1941. By October the Germans had used most of the ready and relatively well trained replacements which were available in June 1941. It was mainly poor strategic contingency planning, as well as Wehrmacht doctrine, that prevented personnel recruited in the second half of 1941 from being sent to the East Front until 1942. The German equipment replacements (particularly tanks) were even more mismanaged at the strategic level. Incredibly, the Germans downgraded their replacement army and war economy immediately prior to and in the early stages of Operation Barbarossa. In addition the Germans appear to have held back certain critical replacements such as tanks, apparently to build up new units in the west.

All these factors are modelled in the German Fully Integrated Land and Air Resource Model. In this case the actual replacements sent to the East Front are used, and the model serves to highlight the strategic blunder of invading the USSR whilst simultaneously downgrading your war economy!

New Equipment

An Integrated Land and Air Resource Model ensures combat units do not receive new equipment historically too early or too late in the campaign.

This result is automatic in a good Fully Integrated Land and Air Resource Model.

If the TOE of combat units is used as the primary indicator of strength in any military simulation (as opposed to each unit's actual strengths) then specific weapons and other equipment are often assumed to have been available when historically this was not the case. This is because TOEs often called for new equipment that was still in the later stages of testing, was not yet in series production, was still in very limited production, or was not yet released to combat units for technical reasons.

A good example of this in 1941 is the availability of Soviet anti-tank rifles. According to the 29th July 1941 rifle division TOE (or Soviet *Shtat*), a rifle division was authorised 18 14.5mm PTRD 1941 or 14.5mm PTRS 1941 anti-tank rifles. However AT rifles were only generally issued in November 1941 because ammunition for them was not in production until late in 1941. This was the case even though AT rifle production started well before June 1941.[16] Red Army units fully equipped with AT rifles often appear far too early in many Barbarossa simulations, particularly in tactical-operational level simulations.

In other cases a weapon system may have been available in significant numbers, even though common perception is that only a few were available. Because the FILARM model is tracking all significant resources (including production and numbers in service) it ensures that newly available weapon systems are included in the actual strength of units, and at the historically correct time.

An example of receiving equipment too late in some Barbarossa simulations is the T-34 tank (a very famous example in fact). Many accounts of Operation Barbarossa claim, or at least imply, that the T-34 surprised the German Army in the winter counter-offensive of 1941. Some military simulations follow this line. In fact, on 22nd June 1941 the Soviets had already manufactured 1 225 T34s, of which 895 were allocated to combat units and 62 were in training units or depots (957 tanks issued).[17] Of these, 918 T34s were available for combat in the Western Military Districts in June-July 1941.[18] Almost all these tanks were irrecoverably lost from June to August 1941. By the end of 1941 the Red Army had lost 2 300 T34s, most of them well before the winter counter-offensive.[19]

Operational Freedom of Action (within the Simulation)

An Integrated Land and Air Resource Model allows the military simulation 'commander' to have the same level of operational freedom as the historical protagonists.

The Soviet FILARM model highlights the fact that a substantial number of new divisions, which the Soviets are credited with mobilising in 1941, were in fact existing divisions that were simply renamed (and occasionally revamped). Essentially, the Soviets officially disbanded many of these units by simply renaming them as a 'new' units, and usually (but not always) adding some

[16] G.F. Krivosheev, et al, Soviet Casualties and Combat Losses in the Twentieth Century, ed. Colonel General G.F. Krivosheev, Greenhill Books, London, 1997, p. 246, table 95. Also, C.C. Sharp, Red Tide: Soviet Rifle Divisions Formed From June to December 1941, Soviet Order of Battle World War II: Volume IX, George F. Nafziger, West Chester, OH, 1996, p. 119.
[17] S. Zaloga, P. Sarson, T36/76 Medium Tank 1941-1945, Osprey Military (Reed International Books), London, 1994, p. 9.
[18] Refer to Part IV 6. 18) a. - 'The Soviet Fully Integrated Land and Air Resource Model - The Actual Strength of all Soviet Land Combat Units in a Deployed (D) State on 22nd June 1941 - The Soviet Tank Deployment Matrix - The Deployment and Composition of Red Army and NKVD Armoured Forces on 22nd June 1941'. Includes: 863 T34s in Deployed (D) units in the Western Military Districts, 9 T34s in the South Western Front training and repair, 30 T34s picked up by the 1st Mechanised Division from training units in Moscow while on its way to the front as part of Stavka Reserves, and 16 in 50th Tank Division in Stavka Reserves.
[19] G.F. Krivosheev, et al, Soviet Casualties and Combat Losses in the Twentieth Century, ed. Colonel General G.F. Krivosheev, Greenhill Books, London, 1997, p. 252, table 95.

additional resources from reserves.[20] As the underlying principle of the integrated resource model is 'the conservation of resources' within the armed forces of a country, then in order for these 'new' divisions to come into existence, the existing 'old' divisions (providing the resources) have to be removed from the Order of Battle (OOB).

However if all unit disbandments are pre-ordained and hence pre-programmed into a military simulation according to historical timelines, it would have a severe and unrealistic impact on the operational options available to the Soviet simulation 'commander'. Historically the Soviets would not have disbanded or reorganised a division in the middle of a battle, where it would most likely be holding a critical position. Correspondingly in the simulation, an artificial situation would occur where the Soviet simulation commander would always be in danger of loosing a division in the line at a critical moment. In fact, his or her entire strategy in the simulation would be dictated by the historical disband decisions made in a potentially different situation and a different historical context. The simulation commander would have much less freedom of action in planning their campaign than the historical commanders did.

For example, the 131st Mechanised Division (9th Mechanised Corps-Southwestern Front) was renamed the 131st Rifle Division on 3rd July 1941, after being committed to heavy combat in June 1941. Most of its tanks in its tank regiment were gone by early July 1941 and a new rifle regiment was added from reserves to replace its expended tank regiment. This is the historical context.

Now consider what might happen if the Southwestern Front's simulation commander has managed to keep his 9th Mechanised Corps intact through June 1941 by not committing it to combat, and building it up with replacements in a rear area. This was historically not the decision made. In the simulation, the Soviets are therefore ready for a major counter-attack against Army Group South in early July 1941. The counter-attack's success depends on the tanks and mobility of the corps' 131st Mechanised Division. Suddenly (on 3rd July), without ever going into combat, the 131st Mechanised Division becomes a relatively immobile rifle division with no tanks and few trucks: these have all gone into reserve. Subsequently the counter-attack cannot happen, even though the units involved had never seen combat! The simulation is implementing a command decision made in a completely different historical situation. In other words simply implementing decisions made in a historically different context, can lead to unrealistic restrictions and ahistorical situations. Unfortunately in many existing simulations of Operation Barbarossa (and other military campaigns) this is exactly what happens.

The reader should bear in mind here that as the simulation commander, higher command decisions (including disbandment of combat units) should become yours. The decision to either, immediately commit the 131st Mechanised Division into combat (as was done historically), hold it in reserve for a counterattack, or simply disband it for its resources, should be the simulation commander's. The actual historical decision was made by the Soviet high command based on the specific historical situation at that time: the simulation commander should be allowed at least the same freedom of action as the historical protagonists. The disbandment of the 131st Mechanised Division should therefore not be pre-ordained, and hence pre-programmed, in any military simulation striving to achieve historical accuracy and avoid unrealistic situations.

The FILARM model realistically simulates the effect of different command decisions, whilst still keeping the military simulation in historical context. For example, if the 131st Mechanised Division was immediately disbanded in the simulation, then the 131st Rifle Division would arrive

[20] Refer to Part I 3. 4) e. - Military Simulations, and the General Structure of the Integrated land and Air Resource Model - The Structure of the Fully Integrated Land and Air Resource Model (FILARM) - Combat Unit Processes Inside the FILARM Model - Disband and Shatter process' for an explanation on the use of the 'disbandment processes' in the FILARM model. This process enables existing resources in existing combat units to be used in forming so called 'new' combat units.

on the battlefield at approximately one third strength (representing the genuinely new rifle regiment from reserves), and other Red Army combat units would benefit from additional replacements. Alternatively if the 131st Mechanised Division was held in reserve for a counter-attack, then the counter-attack combat would be resolved, the 131st Rifle Division would arrive on the battlefield at approximately one third strength, and other Red Army combat units would not receive the additional replacements. In short, the power of the FILARM model allows realistic operational freedom of action because it works as a complete system.

A way of preserving the integrated model, not limiting the operational options open to any simulation commander, and not reducing the historical mobilisation schedule, are examined in detail in Part IV of this book: the Soviet Fully Integrated Land and Air Resource Model (FILARM).[21]

[21] Refer to Part IV 7. - 'The Soviet Fully Integrated Land and Air Resource Model - Soviet Mobilisation After 22nd June 1941: The Actual Strength of all Soviet Land Combat Units Mobilised from 22nd June to 31st December 1941'.