Supplementary material

This appendix contains supplementary material to the paper *WARGEAR: 'real time' generation of detailed layout plans of surface warships during early stage design* by J.J. le Poole et al, submitted to the Ocean Engineering journal.

Supplementary material to Section 4.5

In an attempt to falsify the allocation method outlined in Section 4.5, the following variations to the method have been tested.

1. The fraction between the degrees of spaces and compartments is removed from $P_{allocation,ij}$.
2. The fraction between the areas of spaces and compartments is removed from $P_{allocation,ij}$.
3. The order in which spaces are allocated is determined via sorting by ascending degree only.
4. The order in which spaces are allocated is determined via sorting by descending area only.

Each variation is separately tested on two sets of input. Each variation is tested 10,000 times with randomly generated roulette wheel positions x. Besides the four variations the baseline allocation method without alternations, i.e. variation 0, is tested on the test case input. The two input sets contain 100 and 75 spaces, to be allocated to 9 and 14 compartments respectively. The two input sets differ mainly on the number of interactions between compartments. The former has less interactions, i.e. it's less likely that a non-optimal allocation of some spaces will lead to problems for other spaces. Also, the compartments in the latter set are relative small, which could make allocation difficult. However, the total available area in comparison to the total required area is larger in the latter set (30% more area available than required) than in the former set (16%), which could compensate for the challenge posed by size of the compartments. Details on space and compartment sizes for the two cases can be found in Tables A3, A4, and A5.

The results of the two tests are summarised in Table A2. The results show that for the first test variation 0, 2 and 3 outperform variation 1 and 4. However, for the second test, variation 4 outperforms all other variations. At the same time, variation 0, 2 and 3 perform comparable and significantly outperform variation 1. The difference in the performance of variation 4 for the two tests might be an indication that the variations are sensitive to the space list and the allocation of spaces to functional blocks. The results indicate that taking the required area of spaces and available area in compartments into account is important. The negative result of variation 1 (and 4) show that it is important to take the degree of compartments and spaces into account.

Further, the area utilisation of compartments is investigated, i.e. to which extent do the variations use the available area in compartments? For sake of brevity only the three overall best performing variations, i.e. variation 0, 2 and 3, are discussed here. Figure A1 provides the mean, median, minimum, and maximum area utilisation over 10,000 allocation attempts for test case 2. The following main observations can be made:

1. Variation 0 and 3 perform similarly, with exception for compartment 3, where the median utilisation of variation 0 is lower than of variation 3.
2. The mean area utilisation of variation 2 differs from variation 0 and 3 in almost half of the compartments. In some cases the utilisation is higher and in other lower. A high compartment utilisation at this point in the layout generation process could be an indication for design integration issues later on, when spaces are actually arranged (see Section 4.6) and connected (see Section 4.7).
3. The minimum area utilisation of variation 2 is frequently more than ten percent point lower than variation 0 and 3, indicating that for these allocations either not all spaces could be allocated, or the other compartments have a (too) high utilisation as discussed above.

Concluding, the baseline methodology (variation 0) outperforms variation 3 with regards to the number of allocated spaces, and provides a slightly more balanced allocation from a compartment utilisation perspective than variation 2. Therefore the initial proposed allocation method remains best, and is used further in the model.

Table A2
Results of 10,000 allocation attempts for five variations to the allocation method. [1]: Out of 100 spaces times 10,000 attempts. [2]: Out of 75 spaces times 10,000 attempts

	Test case 1 (100 spaces)		Test case 2 (75 spaces)	
	Number of non-allocated spaces[1]	% of arranged spaces	Number of non-allocated spaces[2]	% of arranged spaces
0	2	0.0002	2249	0.2999
1	729	0.0729	28381	3.7841
2	0	0.0000	1627	0.2169
3	1	0.0001	3510	0.4680
4	11089	1.1089	0	0.0000

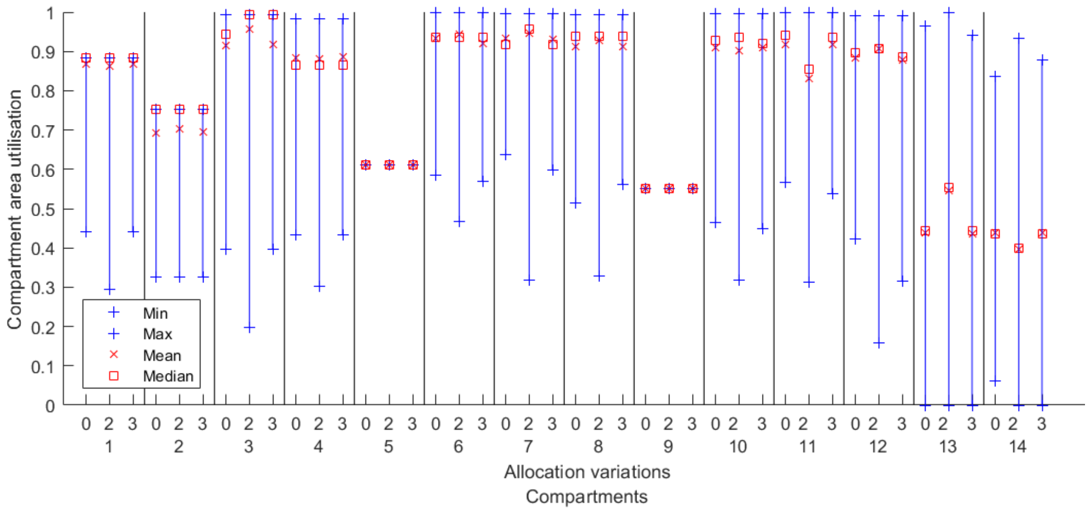


Figure A1: Compartment area utilisation (fraction of total available area) for each compartment for variations 0, 2 and 3 in test case 2.

Table A3
Compartment area for allocation test case 1 and 2.

Test case 1	Compartment	1	2	3	4	5	6	7	8	9
	Area [m^2]	288.0	288.0	287.3	288.0	251.3	288.0	288.0	288.0	288.0
Test case 2	Compartment	1	2	3	4	5	6	7		
	Area [m^2]	135.9	153.0	100.6	92.6	163.6	128.2	125.4		
	Compartment	8	9	10	11	12	13	14		
	Area [m^2]	106.7	90.7	129.4	176.4	94.8	119.1	164.9		

Table A4
Space area and allowed allocation of 100 spaces to nine compartments for allocation test 1.

Space number	Area [m^2]	Compartments 1	2	3	4	5	6	7	8	9	Space number	Area [m^2]	Compartments 1	2	3	4	5	6	7	8	9
1	115						1				51	20	1	1	1				1	1	
2	125						1				52	20	1	1	1				1	1	
3	130					1					53	20	1	1	1				1	1	
4	50					1					54	20	1	1	1				1	1	
5	50				1						55	20	1	1	1				1	1	
6	50				1						56	20	1	1	1				1	1	
7	40				1						57	20	1	1	1				1	1	
8	30				1						58	20	1	1	1				1	1	
9	30				1						59	20	1	1	1				1	1	
10	25				1						60	20	1	1	1				1	1	
11	20									1	61	20	1	1	1				1	1	
12	12									1	62	20	1	1	1				1	1	
13	12									1	63	20	1	1	1				1	1	
14	12									1	64	20	1	1	1				1	1	
15	12									1	65	20	1	1	1				1	1	
16	12									1	66	20	1	1	1				1	1	
17	12									1	67	20	1	1	1				1	1	
18	12									1	68	20	1	1	1				1	1	
19	12									1	69	20	1	1	1				1	1	
20	10							1	1	1	70	20	1	1	1				1	1	
21	10							1	1	1	71	20	1	1	1				1	1	
22	10							1	1	1	72	20	1	1	1				1	1	
23	10							1	1	1	73	20	1	1	1				1	1	
24	10							1	1	1	74	20	1	1	1				1	1	
25	10							1	1	1	75	20	1	1	1				1	1	
26	10							1	1	1	76	20	1	1	1				1	1	
27	10							1	1	1	77	20	1	1	1				1	1	
28	10							1	1	1	78	20	1	1	1				1	1	
29	10							1	1	1	79	20	1	1	1				1	1	
30	10							1	1	1	80	20	1	1	1				1	1	
31	15							1	1	1	81	20	1	1	1				1	1	
32	15							1	1	1	82	20	1	1	1				1	1	
33	15							1	1	1	83	20	1	1	1				1	1	
34	15							1	1	1	84	20	1	1	1				1	1	
35	15							1	1	1	85	20	1	1	1				1	1	
36	15							1	1	1	86	20	1	1	1				1	1	
37	15							1	1	1	87	20	1	1	1				1	1	
38	15							1	1		88	20	1	1	1				1	1	
39	15							1	1		89	20	1	1	1				1	1	
40	15							1	1		90	20	1	1	1				1	1	
41	15							1	1		91	20	1	1	1				1	1	
42	15							1	1		92	20	1	1	1				1	1	
43	15							1	1		93	20	1	1	1				1	1	
44	15							1	1		94	20	1	1	1				1	1	
45	15							1	1		95	20	1	1	1				1	1	
46	20	1	1	1				1	1		96	20	1	1	1				1	1	
47	20	1	1	1				1	1		97	20	1	1	1				1	1	
48	20	1	1	1				1	1		98	20	1	1	1				1	1	
49	20	1	1	1				1	1		99	20	1	1	1				1	1	
50	20	1	1	1				1	1		100	20	1	1	1				1	1	

Table A5
Space area and allowed allocation of 75 spaces to fourteen compartments for allocation test 2.

Space nr.	Area [m^2]	Compartments 1	2	3	4	5	6	7	8	9	10	11	12	13	14	Space nr.	Area [m^2]	Compartments 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	10		1	1												39	15				1		1	1	1		1	1	1		
2	35		1	1												40	15				1		1	1	1		1	1	1		
3	20		1	1												41	15				1		1	1	1		1	1	1		
4	10													1	1	42	15				1		1	1	1		1	1	1		
5	10													1	1	43	15				1		1	1	1		1	1	1		
6	10										1	1	1	1	1	44	15				1		1	1	1		1	1	1		
7	10										1	1	1	1	1	45	20	1		1	1		1	1	1						
8	10										1	1	1	1	1	46	20	1		1	1		1	1	1						
9	10										1	1	1	1	1	47	20	1		1	1		1	1	1						
10	10										1	1	1	1	1	48	20	1		1	1		1	1	1						
11	10										1	1	1	1	1	49	20	1		1	1		1	1	1						
12	10										1	1	1	1	1	50	20	1		1	1		1	1	1						
13	13										1	1	1	1	1	51	20	1		1	1		1	1	1						
14	13										1	1	1	1	1	52	20	1		1	1		1	1	1						
15	13										1	1	1	1	1	53	20	1		1	1		1	1	1						
16	13										1	1	1	1	1	54	20	1		1	1		1	1	1						
17	13										1	1	1	1	1	55	20	1		1	1		1	1	1						
18	13										1	1	1	1	1	56	20	1		1	1		1	1	1						
19	13										1	1	1	1	1	57	20	1		1	1		1	1	1						
20	13										1	1	1	1	1	58	20	1		1	1		1	1	1						
21	13										1	1	1	1	1	59	20	1		1	1		1	1	1						
22	13				1		1	1	1		1	1	1			60	20	1		1	1		1	1	1						
23	13				1		1	1	1		1	1	1			61	20	1		1	1		1	1	1						
24	15				1		1	1	1		1	1	1			62	20	1		1	1		1	1	1						
25	15				1		1	1	1		1	1	1			63	20	1		1	1		1	1	1						
26	15				1		1	1	1		1	1	1			64	20	1		1	1		1	1	1						
27	15				1		1	1	1		1	1	1			65	20	1		1	1		1	1	1						
28	15				1		1	1	1		1	1	1			66	20	1		1	1		1	1	1						
29	15				1		1	1	1		1	1	1			67	20	1		1	1		1	1	1						
30	15				1		1	1	1		1	1	1			68	20	1		1	1		1	1	1						
31	15				1		1	1	1		1	1	1			69	20	1		1	1		1	1	1						
32	15				1		1	1	1		1	1	1			70	20	1		1	1		1	1	1						
33	15				1		1	1	1		1	1	1			71	20	1		1	1		1	1	1						
34	15				1		1	1	1		1	1	1			72	20	1		1	1		1	1	1						
35	15				1		1	1	1		1	1	1			73	50									1					
36	15				1		1	1	1		1	1	1			74	100					1									
37	15				1		1	1	1		1	1	1			75	50		1												
38	15				1		1	1	1		1	1	1																		

Table A6
Ten sets of spaces with varying required area used in the space arrangement test case.

Space	Space variations									
nr.	1	2	3	4	5	6	7	8	9	10
1	20	20	20	40	100	100	30	43	100	100
2	20	20	20	40	50	100	30	43	100	100
3	20	20	20	20	50	50	30	34	100	100
4	20	20	20	20	50	50	30	34	100	100
5	20	20	20	20	50	20	30	27		20
6		20	20		20	20	25	27		20
7		20	20		20	10	25	27		20
8		20	20		20	10	25	27		20
9		20	20		20	10	25	23		
10		20	20		20	10	25	23		
11			20				20			
12			20				20			
13			20				20			
14			20				20			
15			20				20			

Supplementary material to Section 4.6

This section elaborates the performance of the new cross correlation based space arrangement method, presented in Section 4.6. To do so, the performance of the cross-correlation arrangement method will be compared to the performance of the seed and growth algorithm previously used in WARGEAR [31]. Both algorithms will be used to arrange different sets of spaces in various positioning matrices. Also, the performance of the various space order, position selection, and initial space orientation will be investigated.

Space variations

The performance of the space arrangement method is tested with various sets of spaces, which are presented in Table A6. The variations include sets of spaces with equal size (variation 1, 2, 3, and 9), sets with spaces with small differences in size (variation 4, 7, and 8), and with a large difference in size (variation 5, 6, and 10). Variation 8 will likely result in spaces with areas larger than RA, as the sizes 23, 34, and 43, when divided by an integer number, result in a modulus.

Positioning matrix variations

Six positioning matrix variations are used in this case study, comprising a square, rectangle, and L-shape positioning matrix, as presented in Table A7. Each of these shapes is sized in relation to the space variations, in two ways:

1. The area is equal to the sum of the area required by the spaces.
2. The area exceeds the sum of the area required by the spaces by 10%.

Arrangement problems where no spare area is available are considered to be harder than the problems where there is void space [48]. The former variation is mainly used to test the performance of WARGEAR, while the latter better represents actual ship design layout problems. Indeed in ship layouts the available area for space arrangement is typically larger than the area strictly required for spaces, as additional area for staircases and passageways is required. Typically margins are used to account for staircases, passageways, and for space arrangement considerations. The grid size in this test case is 1x1 meter.

Arrangement variations

The optimisation algorithm used in this test case is a Particle Swarm Optimisation (PSO). The choice for the PSO will be further elaborated on in Section 4.8. In Table A9 the arrangement options are provided. The number of required variables for each option are also given. An arrangement variation is a combination of one option from each of the three categories. For instance, one variation is 3-A-I, in which the optimisation algorithm is used to determine the arrangement order, using n_{space} variables, the first available position is selected for each space, and the first available orientation is used to determine the size of matrix $\boldsymbol{B}$. For *Position selection* a fifth option is also considered, in which the optimisation algorithm can select one, preferably the best, position selection option from A. to D. This option has been included to investigate whether space and positioning matrix based selection of the position selection method yield better results compared to a fixed position selection method. In total 3 (1.-3.)x5 (A.-E.) x2 (I.-II.) = 30 arrangement variations need to be studied to determine the performance of the cross-correlation space arrangement method. Additionally the seed and growth space arrangement method is also applied for each space and positioning matrix variation.

Table A7
Six different positioning matrices used for space arrangement in the test case. Since the grid size is 1x1 m, for a given a real number x, $\lceil x \rceil$ denotes ceil(x), which returns the least greater integer than or equal to x. For example, $\lceil 1.2 \rceil = 2$.

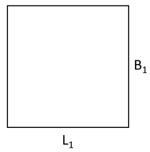
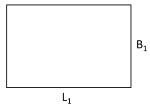
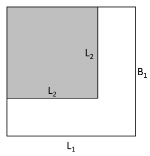
Shape	**Area [m^2]**	**Dimensions [m]**	**Visualisation**
Square 1	$A = \sum_{i=1}^{n_{spaces}} RA_i$	$L_1 = B_1 = \lceil \sqrt{A} \rceil$	
Square 2	$A = 1.1 \cdot \sum_{i=1}^{n_{spaces}} RA_i$	$L_1 = B_1 = \lceil \sqrt{A} \rceil$	As Square 1
Rectangle 1	$A = \sum_{i=1}^{n_{spaces}} RA_i$	$L_1 = \lceil 1\frac{1}{2} \cdot \sqrt{A} \rceil$ $B_1 = \lceil \frac{2}{3} L_1 \rceil$	
Rectangle 2	$A = 1.1 \cdot \sum_{i=1}^{n_{spaces}} RA_i$	$L_1 = \lceil 1\frac{1}{2} \cdot \sqrt{A} \rceil$ $B_1 = \lceil \frac{2}{3} L_1 \rceil$	As Rectangle 1
L-shape 1	$A = \sum_{i=1}^{n_{spaces}} RA_i$	$L_1 = B_1 = \lceil 1\frac{1}{2} \cdot \sqrt{A + L_2^2} \rceil$ $L_2 = 10$	
L-shape 2	$A = 1.1 \cdot \sum_{i=1}^{n_{spaces}} RA_i$	$L_1 = B_1 = \lceil 1\frac{1}{2} \cdot \sqrt{A + L_2^2} \rceil$ $L_2 = 10$	As L-shape 1

Table A8
PSO settings.

	PSO	**Explanation**
NumIt	20	Number of iterations
PopSize	10	Population size
w	0.5	Inertia weight
w_{damp}	0.9	Inertia Weight Damping Ratio
c1	0.5	Personal Learning Coefficient
c2	2.5	Global Learning Coefficient

Two stopping criteria have been used in the test case. First, the optimisation is stopped when an optimal design is found, i.e. all spaces have met their required area and the theoretically maximum objective value has been reached. The objective function is given in Equation 31 and its maximum value is 100. The second stopping criteria is the maximum number of iterations of the optimisation algorithm. The settings of the optimisation algorithm are given in Table A8, and have been established based on experience using WARGEAR. For each variation the time till a stopping criteria is reached, $TimeTillStop$, is stored as well as the best arrangement, and the objective value $BestObjectiveValue$ of that arrangement. To reduce the sensitivity of results to the randomised starting point of optimisation calculations, five runs are completed for each variation.

$$ObjectiveValue = \frac{\sum_{i=1}^{n_{space}} \max(0, RA_i - AA_i)}{n_{space}} \tag{31}$$

The various arrangement methods are assessed based on the $ObjectiveValue$, the number of successful arrangements, as well as on the $TimeTillStop$. Indeed, reduced calculation time is important to enable near-real time feedback to naval architects [19, 32].

Table A9
Arrangement method options. Each arrangement method variation consists of a space order option, a position selection option, and an initial space orientation option.

	Space order	Required variables
1.	Large to small	0
2.	Small to large	0
3.	Optimiser selected order	n_{space}
	Position selection	
A.	First available position	0
B.	Positions closest to CL	0
C.	Positions as far from the compartment's centre	0
D.	Optimiser selected positions	n_{space}
E.	Optimiser selects from A.-D	$n_{space}+1$
	Initial space orientation	
I.	First orientation in $B_{range,dimensions}$	0
II.	Optimisation algorithm selects longitudinal or transverse direction from $B_{range,dimensions}$, when choice is possible	n_{space}
S&G	Seed and growth	n_{space}

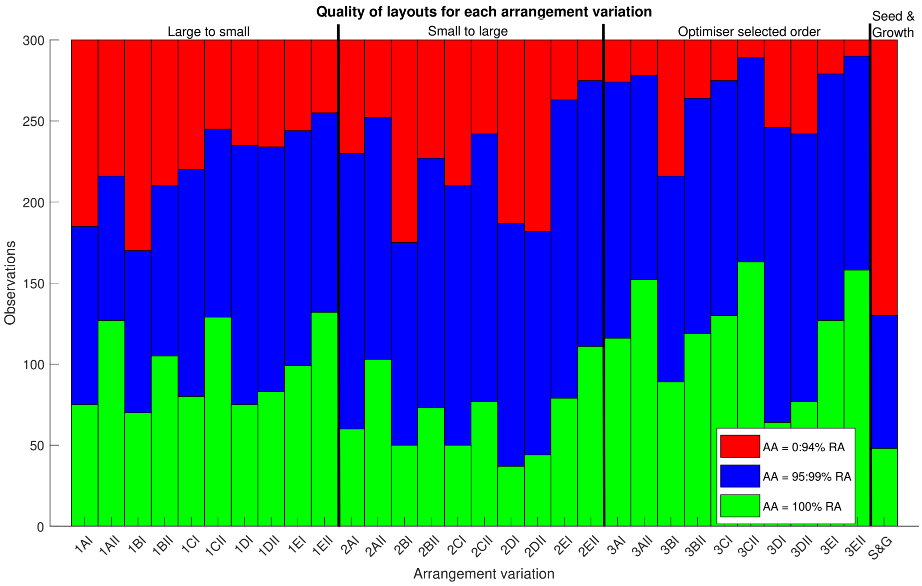


Figure A2: Histogram with quality of layouts for each arrangement variation. See Table A9 for definitions of arrangement variations.

Results

Each arrangement variation has been used to arrange all space variations in all positioning matrix variations. This test has been conducted five times to reduce the likelihood that the optimisation algorithm stopped in local optima, resulting in 10x6x5 = 300 layouts for each arrangement variation. Figure A2 shows a histogram of the quality of resulting layouts for each arrangement variation. The following observations can be made:

1. The optimiser selected space order (3) is more effective than the fixed order methods (1 and 2). This is both the case for layouts that meet their required area (RA), and for layouts with achieved area (AA) = 95 till 99% of RA. However, arranging spaces large to small proves to yield better results than arranging small spaces prior to large ones.
2. Only three arrangement methods are able to fully arrange more than 50% of the layouts, namely 3AII, 3CII, and 3EII. Since the option E actually selects one of the options A till D, a further investigation into this selection was made. Figure A3 shows a histogram with the four position selection options. Again, the options A and C yield better results than the options B and D.
3. The variable initial space orientation (II) consistently outperforms the fixed initial space orientation (I), regardless of the space order and position selection method.
4. The seed and growth arrangement method is outperformed by 28 of the 30 cross-correlation methods based on layouts at 100% RA, and by

all cross-correlation methods if the 95-100% interval is considered. Therefore the change to cross-correlation based arrangement can easily be justified.

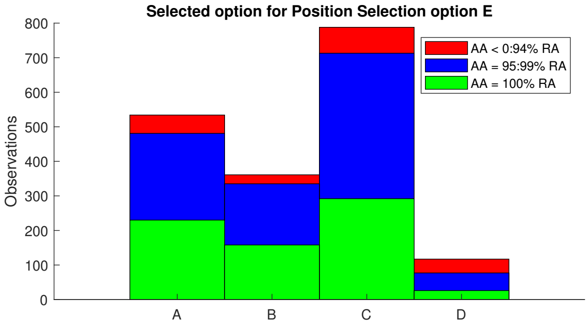


Figure A3: Histogram with success of selected options by position selection option E.

Besides quality concerns, the seed and growth algorithm was found to be time consuming. Therefore the computation time required by the arrangement variations will be considered next, see Figure A4. The main observation to be made is that cross-correlation based methods require up to 1.125 seconds to complete their arrangement attempt, while the seed and growth algorithm requires up to 2.971 seconds. So, based on the lowest speeds of the methods, cross-correlation methods are almost three times faster than the seed and growth algorithm. However, the speed difference between cross-correlation and the seed and growth algorithm is even larger if the average speed is considered. On average cross-correlation based methods require 0.022 seconds to find layouts that meet the required area. In contrast, the seed and growth method requires 0.436 seconds to get the same results. Thus, on average, cross-correlation is 20 times faster than seed and growth.

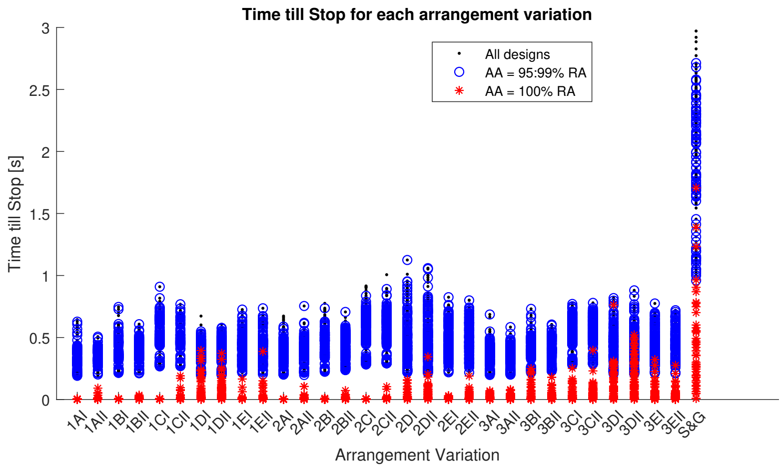


Figure A4: Scatter plot with time till stopping criteria was reached for each arrangement variation.

The test case above shows that cross-correlation methods outperforms the seed and growth algorithm on the two performance criteria, i.e. quality and calculation time. However, in order to select the preferred arrangement method, the performance of the overall methodology should be considered. More elaborate test cases with the WARGEAR methodology showed that there is a tight relationship between space arrangement and local connectivity, see Section 4.7. Indeed, the arrangement of the spaces, and, implicitly, the unused area left between spaces determines how much area needs to be 'carved' from spaces to ensure connectivity. This results in a reduction of the size of arranged spaces, and thus spaces that initially met their required area might fail to meet this criterion after connectivity has been established. This issue is further elaborated on in Section 4.7. The best performing arrangement variations 3AII, 3CII, and 3EII will be further tested in the supplementary materials to Section 5 as well, where the selection options for 3EII are limited to 3AII and 3CII.

Supplementary material to Section 5

The initial case in the notional surface vessel case study presented in Section 5 was one of three tests used to investigate the combination of space arrangement approaches and the passageway carving approach. Indeed, in Section 4.7 the need for a test with the integrated methodology was expressed. In the supplementary materials to Section 4.6, three arrangement variations were found to be performing well (3AII, 3CII, and 3EII).

Table A10
Summary of results of the three initial cases

Test number	A Mimimum F obtained [m^2]	B Minimum number of spaces not-allocated	#B	A|B [m2]	Run time [s]
1a	19.68	0	2	27.72	832.59
1b	15.84	0	175	15.84	764.17
1c	12.60	0	163	12.60	737.05

The three cases elaborated on here are respectively numbered test 1a-1c, where test 1c represents case 1 in Section 5. Based on the results of these three tests the final arrangement variation will be chosen. For details on the case study setup, see Section 5.

The results of the three tests are summarised in Table A10. The results show that arrangement variation 3CII and 3EII (tests 1b and 1c) outperform arrangement variation 3AII (test 1). This can be observed as follows:

1. The final obtained objective score F is lower for tests 1b and 1c than for test 1a. This means that the difference between required and achieved area in test 1a is larger than in tests 1b and 1c.
2. The number of non-allocated spaces in tests 1b and 1c is lower than in test 1a. This is not directly a result of the arrangement variation, since the allocation is steered by the outer optimisation loop (PSO1). However, the behaviour of the arrangement variation does influence the behaviour of PSO1.
3. The objective score F before local connectivity is higher for test 1a than for the final iterations of tests 1b and 1c. This is both caused by a less efficient arrangement of spaces and the non-allocated spaces.

Similar observations can be used to show that test 1c outperforms test 1b. Therefore arrangement variation 3EII will be used in the case study as described in Section 5, and is implemented in the overall WARGEAR methodology.

Tables A11 and A12, and Figure A5 contain input data for the concluding case study.

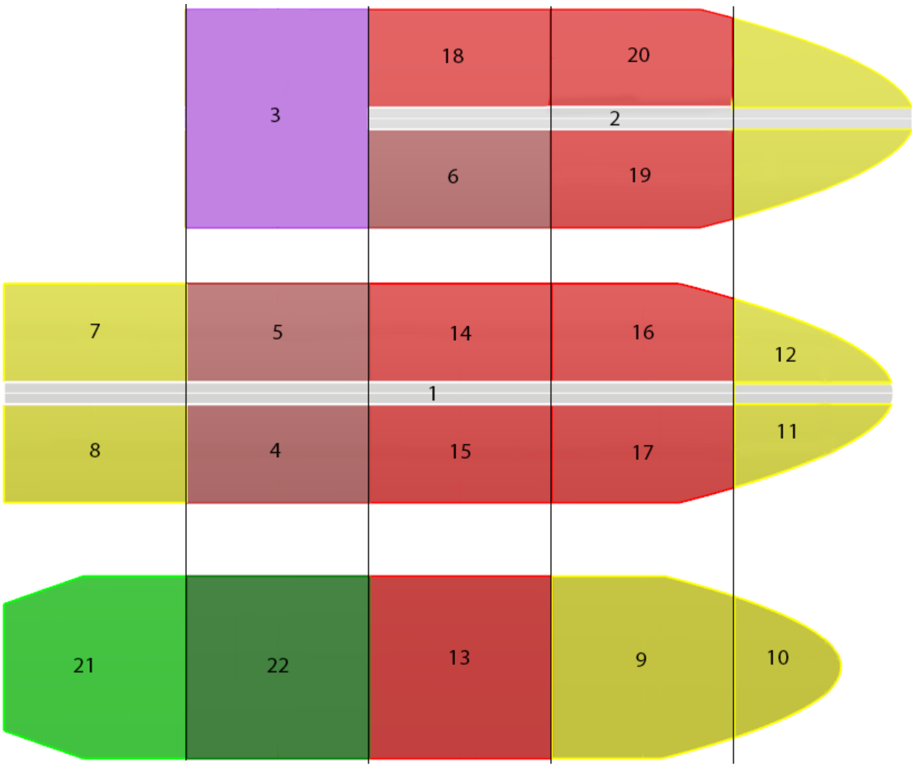


Figure A5: Deck plans of the functional arrangement used in the case study

Table A11
Case study: Space list and space characteristics

ID	Name	Area	AR low	AR high	FBB name	FBB numbers					
1	Store 1	15	0.5	1	Operational rooms and offices	4					
2	Store 2	15	0.5	1	Operational rooms and offices	4					
3	Store 3	20	0.5	1	Operational rooms and offices	4					
4	Mess	35	0.5	1	Accommodation cabins	15					
5	Galley	15	0.5	1	Accommodation cabins	15					
6	Cabin 1	10	0.5	1	Accommodation cabins	13					
7	Cabin 1	10	0.5	1	Accommodation cabins	13					
8	Cabin 1	10	0.5	1	Accommodation cabins	13					
9	Cabin 1	10	0.5	1	Accommodation cabins	13					
10	Cabin 1	10	0.5	1	Accommodation cabins	13					
11	Cabin 1	10	0.5	1	Accommodation cabins	13					
12	Cabin 1	10	0.5	1	Accommodation cabins	13					
13	Cabin 1	10	0.5	1	Accommodation cabins	13					
14	Cabin 2	15	0.5	1	Accommodation cabins	14	16	17	18	19	20
15	Cabin 2	15	0.5	1	Accommodation cabins	14	16	17	18	19	20
16	Cabin 2	15	0.5	1	Accommodation cabins	14	16	17	18	19	20
17	Cabin 2	15	0.5	1	Accommodation cabins	14	16	17	18	19	20
18	Cabin 2	15	0.5	1	Accommodation cabins	14	16	17	18	19	20
19	Cabin 2	15	0.5	1	Accommodation cabins	14	16	17	18	19	20
20	Cabin 2	15	0.5	1	Accommodation cabins	14	16	17	18	19	20
21	Cabin 2	15	0.5	1	Accommodation cabins	14	16	17	18	19	20
22	Cabin 2	15	0.5	1	Accommodation cabins	14	16	17	18	19	20
23	Cabin 2	15	0.5	1	Accommodation cabins	14	16	17	18	19	20
24	Cabin 2	15	0.5	1	Accommodation cabins	14	16	17	18	19	20
25	Cabin 2	15	0.5	1	Accommodation cabins	14	16	17	18	19	20
26	Cabin 2	15	0.5	1	Accommodation cabins	14	16	17	18	19	20
27	Cabin 2	15	0.5	1	Accommodation cabins	14	16	17	18	19	20
28	Cabin 2	15	0.5	1	Accommodation cabins	14	16	17	18	19	20
29	Cabin 2	15	0.5	1	Accommodation cabins	14	16	17	18	19	20
30	Cabin 2	15	0.5	1	Accommodation cabins	14	16	17	18	19	20
31	Cabin 2	15	0.5	1	Accommodation cabins	14	16	17	18	19	20

Table A12
Case study: List with functional building blocks and available area in compartments. [1] YES: these FBBs are not available for space arrangement

FBB number	FBB name	Area	Blocked[1]	Deck	Compartment	Available area
1	Passage ways and staircases	58.5	Yes	1	3	97.92
2	Passage ways and staircases	24	Yes	2	2	51.84
3	Helicopter hangar	120	Yes	2	3	110.16
4	Operational rooms and offices	54.1	No	2	4	110.16
5	Operational rooms and offices	54.1	Yes	3	3	55.08
6	Operational rooms and offices	54.1	Yes	3	4	110.16
7	Void	54.1	Yes			
8	Void	54.1	Yes			
9	Void	95.9	Yes			
10	Void	30.3	Yes			
11	Void	24.9	Yes			
12	Void	24.9	Yes			
13	Accommodation cabins	100.1	No			
14	Accommodation cabins	54.1	No			
15	Accommodation cabins	54.1	No			
16	Accommodation cabins	52.8	No			
17	Accommodation cabins	52.8	No			
18	Accommodation cabins	54.1	No			
19	Accommodation cabins	53.6	No			
20	Accommodation cabins	53.6	No			
21	Propulsion room	93.3	Yes			
22	Generator room	100.1	Yes			